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ABSTRACT

Contemporary technology has many applications that differ from their original usage. Programs sponsored by the National Aeronautics and Space Administration (NASA) need advanced technology and the technologies they generate are exceptionally diverse. The large storehouse of technology built over almost a quarter-century of space research and more than half a century of aeronautical research constitutes a national resource of knowledge for new uses. This publication is intended to heighten public awareness of the technology available for use and its potential for economic and social benefit to the United States. Section 1 outlines NASA's mainline effort and the major problems that generate these new technologies, as well as projected space operations for the 1980s. Section 2 contains a representative selection of products and processes that have emerged from secondary application of NASA technology. Section 3 describes the various mechanisms NASA employs to encourage technology use and lists contact sources for further information about the Technology Utilization Program. Technologies discussed in this volume relate to: (1) Transportation; (2) Consumer and Recreational Products; (3) Computer Technology; (4) Health and Medicine; (5) Industrial Productivity; (6) Environment and Public Safety; (7) Commercial Remote Sensing; and (8) Technology Demonstrations. (CW)

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NASA
National Aeronautics and Space Administration

SE 040 449

Foreword

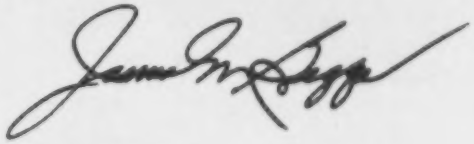
Since its inception 24 years ago, the National Aeronautics and Space Administration has vigorously pursued the goal, set forth by the Congress, of realizing "the potential benefits to be gained from aeronautical and space activities." The results have been impressive.

Much of NASA's effort has centered on development of space systems that produce benefits here on Earth, for example the communications and weather satellites now in operational service. While continuing to advance technology in these areas, the agency is now investigating a whole new range of practical space applications. Already in development or planned for future years are orbital sensing systems for better management of Earth's resources; for life-saving improvements in search and rescue techniques; for studying the causes of earthquakes and other natural disasters toward mitigating their effects; for protecting our environment through better understanding of how it is affected by human activities; and for processing materials in space to create a new range of products that cannot be manufactured on Earth.

Concurrently, NASA has conducted a space science program of extraordinary scope whose underlying aim is acquisition of more knowledge about our own planet Earth and the complex forces that govern it, toward the possibility that we may learn how to control or modify these forces for sweeping benefit to mankind. For the nearer term, this wealth of scientific knowledge provides a broadened base for expanding our national technological capability, a key factor in our competitive position in the world and our standard of living.

Through its aeronautical research, NASA has contributed to the advancement of flight, with attendant benefit to national security and the U.S. economy, to airlines and aircraft manufacturers, to passengers and private plane operators, and to the public at large through improvement of the airplane. This research enables America to remain at the forefront of technology in the increasingly competitive world of aeronautics.

This year, NASA will mark a major milestone with the introduction of the Space Shuttle to regular operational service. The versatile Shuttle will make it possible to perform traditional space tasks more efficiently and to accomplish many types of operations never before undertaken. Thus, it offers a significantly elevated capability for doing useful work in space, heralding an era of even greater opportunity for benefit.



James M. Beggs
Administrator

National Aeronautics and Space Administration

Spinoff 1982

National Aeronautics and
Space Administration

Office of External Relations

Technology Utilization and
Industrial Affairs Division

by James J. Haggerty

April 1982

On the Cover:

A glimpse of tomorrow, reference concepts of a permanent, Shuttle-tended space station, the next logical step in American space development *(see page 16).*

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Introduction

Technology is a significant and productive aspect of 20th century life. It is a key ingredient for increased national productivity, a generator of new conveniences and necessities, and a means of attacking some of mankind's most pressing problems.

By definition, technology is simply knowledge, or technical "know-how." Like other forms of knowledge, it is usable by many people and organizations. There is no better example of technology utilization than the wheel, a Bronze Age invention that has been readapted countless times over the millenia. It served as the departure point for such ancient innovations as the grindstone, the pulley, the spinning wheel and the windlass; it is the cornerstone of such modern transportation components as gears, rotating shafts, propellers and turbines; it has found utility in a great range of minor conveniences from casters to doorknobs.

Few inventions offer such sweeping potential, but contemporary technology can similarly be applied to many uses different from the original application. NASA programs, by their challenging nature, are particularly demanding of technological advance and the technologies they generate are exceptionally diverse. Thus, the large storehouse of technology built over almost a quarter-century of space and more than half a century of aeronautical research constitutes a national resource, a bank of knowledge available for new uses.

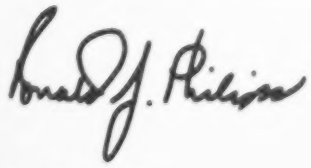
By Congressional mandate, NASA is charged with stimulating the widest possible use of this valuable resource. The agency's Technology Utilization Program provides a link between the technologists, the technology and those who might be able to apply the technology productively. The program's aim is to broaden and accelerate the technology transfer process to create new products, new processes and new jobs, and thus gain substantial dividends on the funds invested in aerospace research. It must be stressed that technology transfer is a two-way street; the potential user/beneficiary must be as aggressive as the originator in seeking to accomplish other uses.

This publication is intended to heighten public awareness of the technology available for utilization and its potential for economic and social benefit to the nation.

Section 1 outlines NASA's mainline effort, the major programs that generate new technology potentially applicable to other possibilities.

Section 2, the focal point of this volume, contains a representative selection of products and processes that have emerged from secondary application of NASA technology.

Section 3 describes the various mechanisms NASA employs to encourage technology utilization and lists, in an appendix, contact sources for further information about the Technology Utilization Program.



Ronald J. Philips
Director, Technology Utilization and Industry Affairs Division

Office of External Relations

National Aeronautics and Space Administration

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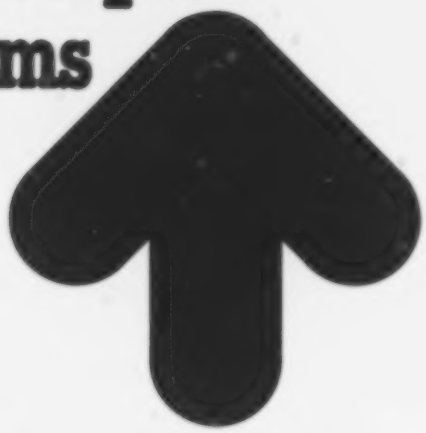
Aerospace Aims



An illustrated summary of NASA's major aeronautical and space programs, their goals and directions, their contributions to American technological growth, and the many ways in which they are producing benefits to Earth's people

Space Operations in the Eighties

The capabilities of the versatile Space Shuttle, coupled with technology being developed for advanced missions, afford broader opportunity for exploiting the promise of space

The April 1981 orbital flight debut of the Space Shuttle was a major milestone in space progress for a number of reasons, principally that it was the first time a spacecraft had returned to Earth in a controlled, airplane-like approach and landing.

But STS-2, the Shuttle's second flight in November, was equally significant. It marked the first time that a spacecraft—the Orbiter *Columbia*—had ever returned to orbit after its initial use. STS-2 thus underlined the most important feature of the Space Shuttle, the fact that the Orbiter and the solid rockets that boost it are reusable. Repetitive use of these two main components of the Shuttle allows large-scale savings in costly equipment formerly used just once. It also permits a degree of operational regularity that makes access to space a matter of routine and significantly elevates NASA's ability to pursue the opportunities for practical Earth benefit that space promises.

Eventually, the Oribiter will fly into space for stays of up to 30 days and open the door to many operations never before accomplished. For example, it will be able to deliver to orbit fully-equipped modules which would be docked together to form a manned space station. Alternatively, it can serve as a space construction base for erecting such large structures as unmanned multipayload platforms or a habitable facility for manufacture of certain items better produced in the gravity-free environment of space.

Those operations are some years down the line. The next three years will be a "breaking in" period for the Shuttle, principal element of NASA's Space Transportation System. It will be a time for learning more about the system's capabilities and limitations, and for developing technology to make possible the advanced missions contemplated. During this period, the Shuttle will

A remote camera at Kennedy Space Center captured this symbolic photo contrasting wings of feathers and "wings" of flame, as the Space Shuttle roared off the launch pad on its historic maiden flight.

begin regular operational service at modest frequencies, averaging about 10 flights a year. For the most part, its assignments will be deliveries of Earth-orbiting payloads, sometimes multiple payloads on a single flight. Other than NASA, payload sponsors include the Department of Defense, the European Space Agency, a number of foreign nations and the operators of several communications satellite systems.

The first three years will see the initial flights of the Spacelab, the human-staffed orbiting laboratory that fits into the Orbiter's cargo bay. On one of the earliest missions, NASA will conduct the first experiment in retrieving a payload from orbit, a capability that will later permit repair of satellites in space or returning them to Earth for rework, extending their useful lives and saving replacement costs. Late in the three-year span, the Shuttle will launch an interplanetary spacecraft. The original Orbiter *Columbia* will be joined by the other three Orbiters of the initial fleet—*Challenger*, *Discovery* and *Atlantis*, in order of service debut.

Beginning in the mid-eighties, Orbiter turnaround time will be substantially reduced and mission frequencies will increase.

Improvements in the Shuttle will boost its weightlifting capacity and its stay-time in space. To accomplish the advanced space operations planned for the latter eighties and beyond, NASA contemplates such additions to the Space Transportation System as orbiting power stations for large-scale electrical supply, orbital transfer vehicles to move astronauts and cargo from low to high Earth orbit, robot systems for in-space construction and maintenance tasks, and a heavy lift vehicle for delivering payloads larger or heavier than the Shuttle can accommodate.

The Space Shuttle program involves the work of many cooperating organizations, principally NASA and the Department of Defense, which will operate a West Coast Shuttle base beginning in the mid-1980s. The European Space Agency is developing the Spacelab component and the National Research Council of Canada is contributing the Orbiter's remote manipulator system.

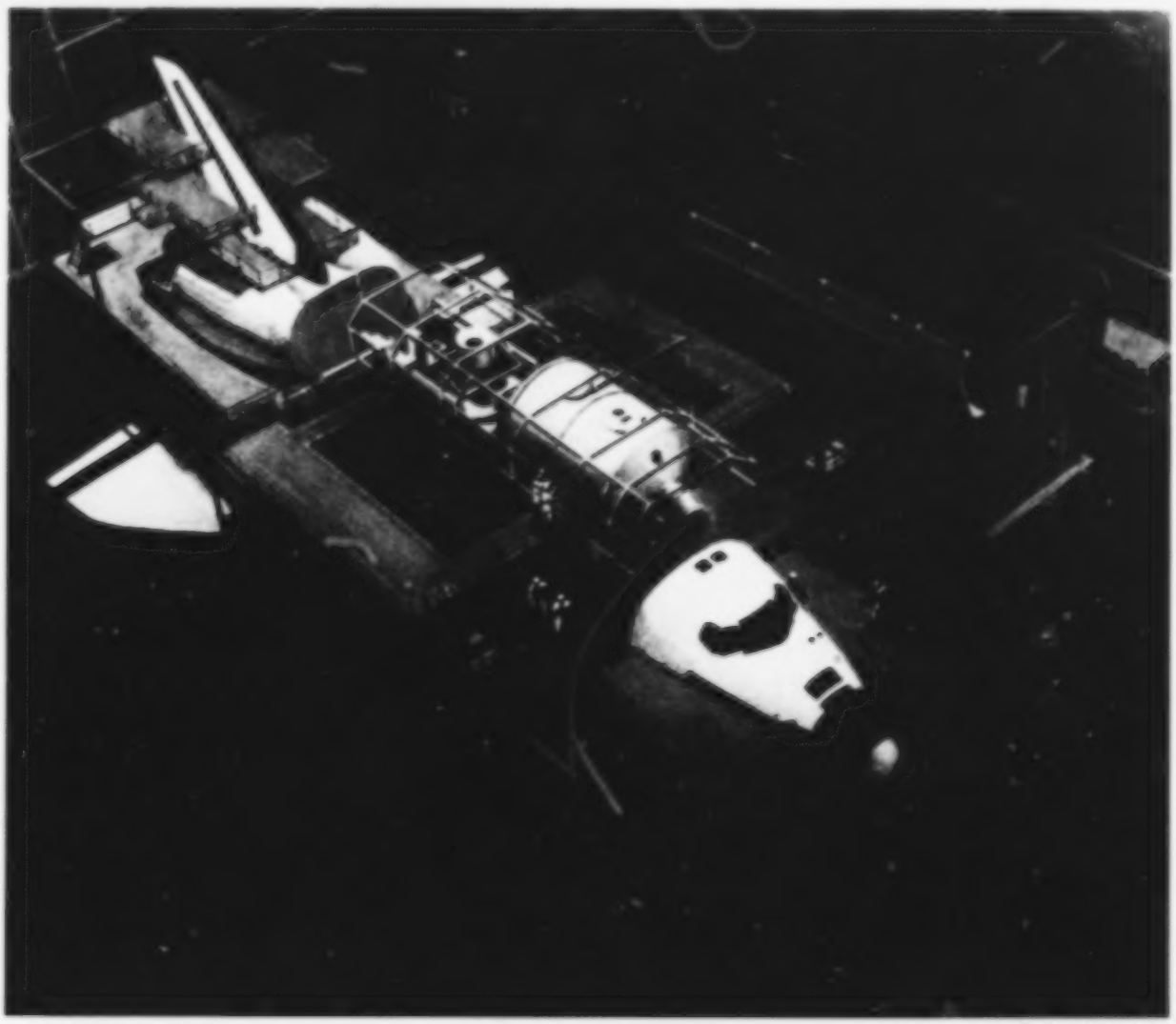
Rockwell International Corporation heads a list of several hundred industrial contractors; Rockwell builds the Orbiter and is also prime contractor for integration of the overall Shuttle system. Both Orbiter and integration contracts are managed by Johnson Space Center. Thiokol Corporation produces the solid rocket boosters and Martin Marietta Corporation supplies the large external fuel tank that feeds the Orbiter's main engines; these contracts are managed by Marshall Space Flight Center. United Space Boosters, Inc. handles launch, recovery and refurbishment of the solid rockets under contract with Kennedy Space Center.

Touching down at Dryden Flight Research Facility on completion of its second flight, the Orbiter Columbia *became the first spacecraft to fly twice.*

Recovery and Refurbishment

At left, the crew of *UTC Freedom* is attaching a line to a recovered solid rocket booster. On a Shuttle flight, the two boosters provide launch thrust for two minutes, then descend by parachute to an ocean rendezvous with *Freedom* and its sister ship *UTC Liberty*. Water is pumped out of the spent rockets so they will float and they are towed back to the launch vicinity. At Cape Canaveral Air Force Station, the rocket casings undergo high pressure cleaning, then are shipped to the manufacturer's plant for reloading with propellants, enabling their reuse in future missions. Booster recovery and refurbishment is expected to be accomplished for about 30 percent the cost of a new pair of rockets. United Space Boosters, Inc., a subsidiary of United Technologies Corporation, operates the recovery ships and handles refurbishment.

The manned Orbiter is similarly refurbished. After a landing, its propellant feedlines are drained and purged for safety, then the spacecraft is moved to the Orbiter Processing Facility (below) at Kennedy Space Center. There it is given a thorough inspection, serviced and repaired as necessary, then fitted with a new payload for the next flight.



Rockwell International

Payload Manipulator

Shown undergoing checkout aboard the Orbiter *Columbia* is the Remote Manipulator System (RMS), used to deposit payloads in space or to retrieve them from orbit. A robot counterpart of the human arm, it has shoulder, elbow and wrist joints, plus a series of electric motors which serve as "muscles." Its "hand" is a cylindrical grappling fixture which grasps a metal prong on the payload to be maneuvered. Controlled by an operator on the Orbiter's flight deck, the RMS lifts a payload out of the Orbiter's cargo bay, positions it in space a safe distance from the Orbiter, then releases it; the process is reversed on payload retrieval missions.

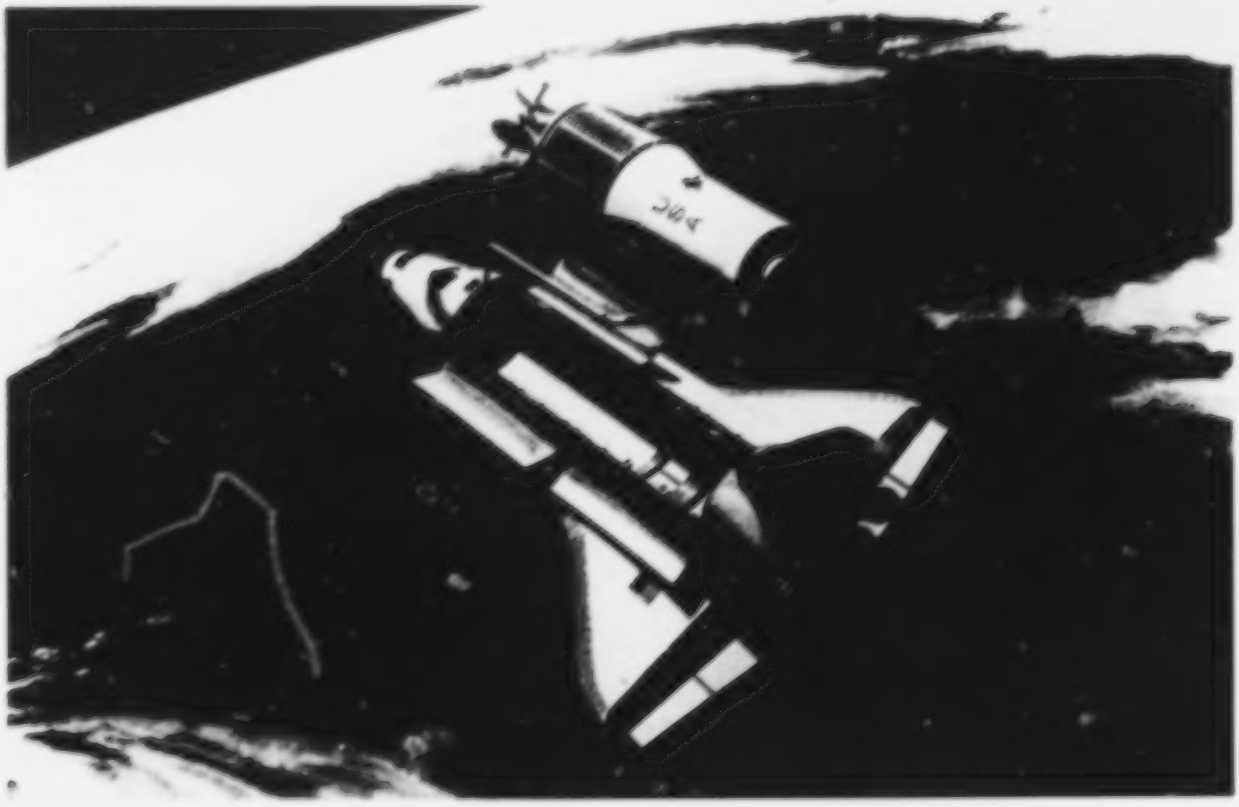
The operator is aided by a number of sensors in the robot arm which send control information to a flight deck computer display. The system is capable of handling any payload the Orbiter can accommodate; in later years, it will also serve as a tool for space assembly and construction tasks. The RMS was developed by the National Research Council of Canada; prime contractor is Spar Aerospace Limited of Toronto, Ontario.

Upper Stages

The Space Shuttle Orbiter operates at altitudes below 700 miles, but many payloads have to go higher to perform their design functions. For example, commercial communications satellites and other applications spacecraft must have line-of-sight contact with large segments of Earth. They are sent to an altitude of 22,300 miles in what is known as a "geosynchronous" orbit. At that altitude, the spacecraft's orbital velocity is synchronized with Earth's speed of rotation, so that the satellite figuratively remains stationary with respect to a point on Earth.

Delivery of geosynchronous and other high altitude payloads is a two-step process in which the Orbiter serves as a "first stage" launch vehicle. The secondary boost is provided by a non-reusable "upper stage" rocket propulsion system affixed to the payload in the Orbiter's cargo bay. The Orbiter's crew deposits the combined payload upper stage in low Earth orbit, then the upper stage rocket is ignited to boost the spacecraft to higher altitude or, in the case of interplanetary explorers, to deep space trajectory.

The initial Space Transportation System includes two types of solid propellant upper stages. At right, being prepared for mating to a communications satellite (left), is the Payload Assist Module, also known as the Spinning Solid Upper Stage (SSUS) because it spins like a gyroscope to maintain stability. Developed by McDonnell Douglas Corporation, the SSUS is built in two versions for different sizes of small-to-medium payloads. For larger payloads, NASA will use the Inertial Upper Stage (below) developed by the Department of Defense. This system is built by Boeing Aerospace Company under contract with the Air Force Space Division.

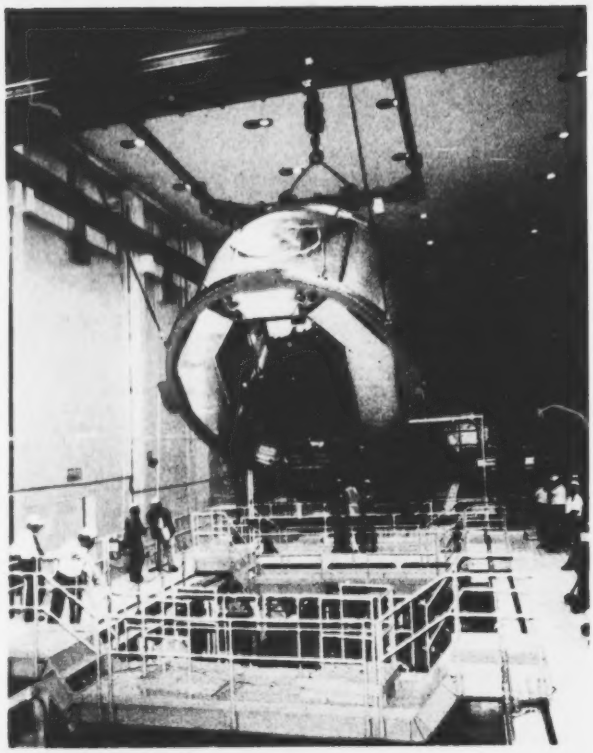


Tracking and Data Relay

The next step in upgrading the capability of the Space Transportation System is provision of an advanced communications relay system exemplified by the Tracking and Data Relay Satellite (TDRS) pictured In the past, spacecraft tracking and Earth space communications were handled by ground stations and tracking ships, but there were "blind spots"—periods when spacecraft were not within range of a receiving station. The new Tracking and Data Relay Satellite System will obviate almost all such communications interruptions. It consists of two TDRS relay stations operating in geosynchronous orbit (22,300 miles) and a ground terminal at White Sands, New Mexico. "Visible" to orbiting spacecraft nearly full time, the TDRS satellites will relay voice, video, commands and data to and from Earth control centers. The relay satellites are built by TRW Inc.; the two NASA satellites, along with a backup in orbit and another intended for commercial use, will be operated by Space Communications, a subsidiary of Western Union, Fairchild Industries and Continental Telephone.

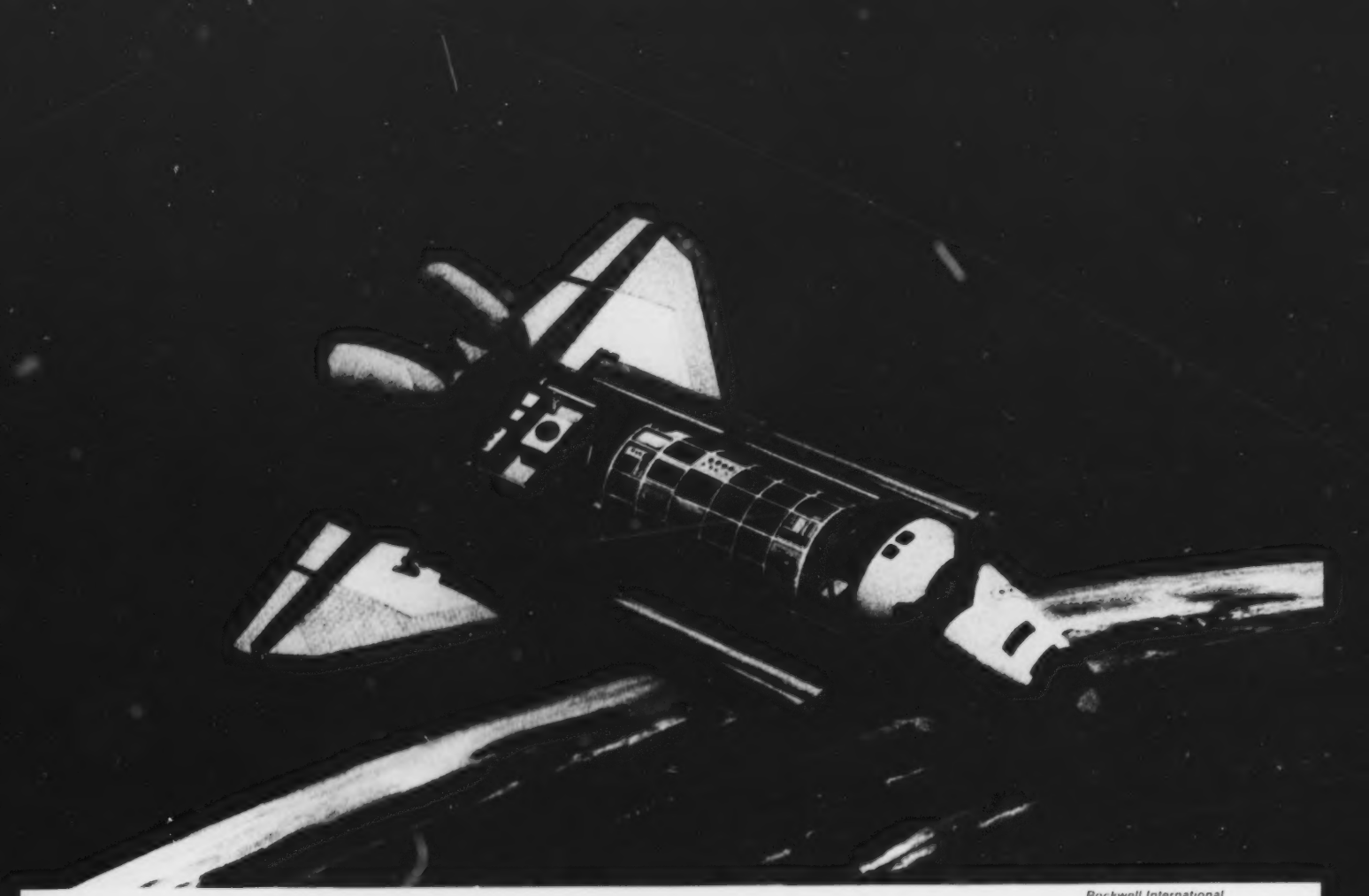
Spacelab

At right, Kennedy Space Center technicians are lowering a test version of a Spacelab segment into a mockup of the Shuttle Orbiter cargo bay. Begun in 1981, mockup tests are intended to check out procedures for installing flight versions of Spacelab (below) in the Orbiter. A complete laboratory that remains within the Orbiter throughout a flight, Spacelab will make possible—beginning in 1983—a variety of human-directed experiments in the space environment. Its main elements are a two-segment pressurized laboratory module, where non-astronaut investigators can work in shirtsleeve conditions, and a non-pressurized instrument pallet, mounted in the open cargo bay for experiments that require direct exposure to space. These elements can be flown in a number of different combinations, for example, the manned laboratory with one or two pallets, or as many as five pallets without the laboratory module; in the latter instance, experiments are controlled from the Orbiter's flight deck. Spacelab is being developed by the European Space Agency, whose activities are coordinated by Marshall Space Flight Center.



Space Power Systems

Electrical power for the Space Shuttle Orbiter's equipment and experiments is provided by fuel cell powerplants which produce electricity by chemical reaction. Three such powerplants generate sufficient power for seven days normal operation. But for some planned missions, on-board equipment will demand greater power and longer stay-time in space will be required. To meet electricity needs for such missions, NASA is developing the Power Extension Package (PEP) shown, a large array of solar cells which convert sunlight into electrical energy. Compactly folded during the trip to orbit, the PEP will be unfurled in space to serve as a 12.5 kilowatt supplementary power station. PEP is the first step in contemplated development of even larger space power systems for such future requirements as a manned space station, a space manufacturing facility, or giant antennas for advanced communications services. These systems, to be constructed in space, would provide electrical power of 200 to 500 kilowatts.



Rockwell International

Space Exposure Facility

In the 1973–74 Skylab program, American astronauts remained in space as long as 85 days and provided an information base on the effects of protracted weightlessness and space radiation. Looking toward possible future missions of much longer duration, scientists want to know a great deal more about long-term exposure to the space environment. They are interested not only in the biological aspects, but also in how space radiations affect materials, structures and on-board equipment over extended periods.

Toward that end, NASA is developing the Long Duration Exposure Facility (LDEF), a 30-foot-long cylindrical structure containing 47 separate scientific and technical experiments arranged in trays around its outer circumference. Shown in the Shuttle Orbiter's cargo bay, the LDEF will be launched in 1984 and deposited in an orbit more than 300 miles high. A diverse variety of samples, including materials, coatings, solar cells, electronic parts and biological specimens, will be passively exposed to the space environment for about one year. The Shuttle Orbiter will then retrieve the LDEF and return it to Earth for detailed examination of the specimens, which is expected to provide information important to the design of future spacecraft and on-board equipment. Managed by Langley Research Center, the LDEF program involves about 100 investigators from government agencies, private companies, universities and eight foreign nations.

Space Construction

At left, technicians at Langley Research Center are simulating erection of a space structural segment by joining tubes made of composite material. They are using a ground-test version of a Langley-developed mobile work station, forerunner of a system that would allow a pair of pressure-suited astronauts, operating from the Space Shuttle Orbiter, to assemble large structures in orbit without expending great amounts of energy; they would be attached by foot restraints to the work station, freeing their hands for assembly tasks. The experimental station is designed to uncover difficulties that might be encountered and to identify additional aids for improving astronaut efficiency in construction jobs.

The mobile work station is one example of a number of study and technology development projects aimed at exploiting the Space Transportation System's capability for construction work. In one approach, structural components would be pre-assembled on Earth, collapsed into compact packages for Shuttle delivery, then expanded to original form in orbit. For erection of habitable structures, a technique being studied involves Shuttle delivery of fully-equipped modules which would be docked together to form a space station. A third approach involves in-space fabrication and joining of lightweight beams. The artist's conception below depicts a space facility assembled by these techniques.

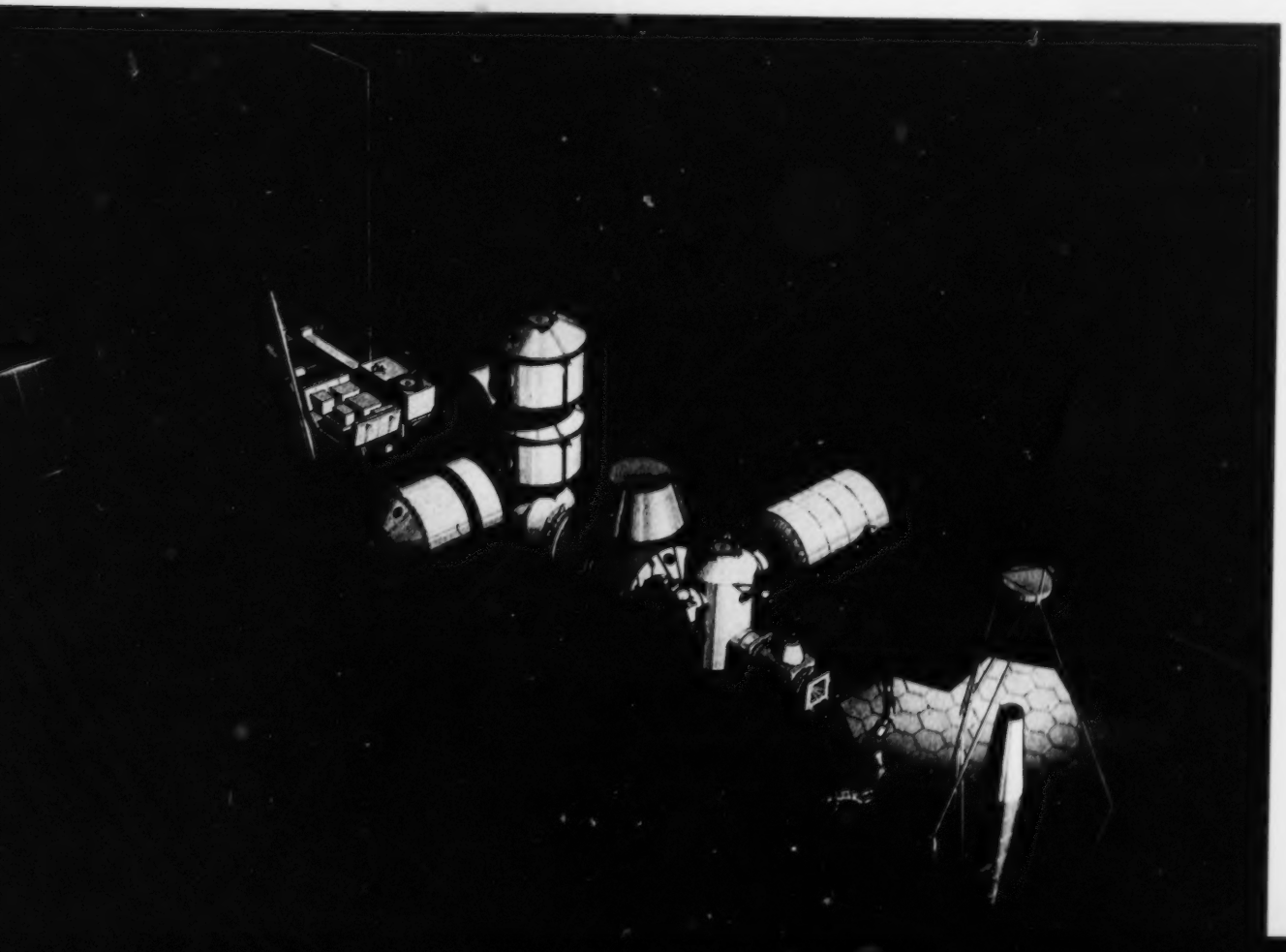
Space Station

Since the inception of the space program, a major goal has been establishment of a permanent manned station in orbit. Now considered the next logical step in American space development, the station—an initial version capable of later expansion—could be in orbit by 1990. The advent of the Space Transportation System makes the station possible by providing routine access to orbit. In fact, the Space Shuttle was conceived with a space station in mind. The Shuttle enables the facility to be built in modular fashion by delivering the various elements for assembly in orbit. With the aid of industry contractors, NASA is conducting studies on how the contemplated station might be deployed, expanded and resupplied, and how it would increase the efficiency of space operations planned for the latter years of the century.

A permanently orbiting station offers a number of advantages in operational flexibility. It would provide a stable, long-duration platform for either unmanned or human-directed scientific experiments; for investigating commercial applications of space, particularly in the field of materials processing; for demonstrating and validating new technologies for Earth or space use; and for orbital assembly, checkout, launch and recovery of increasingly large and complex payloads. It would also provide a manned space presence from which the Department of Defense can develop capabilities and experience essential for the nation's security.

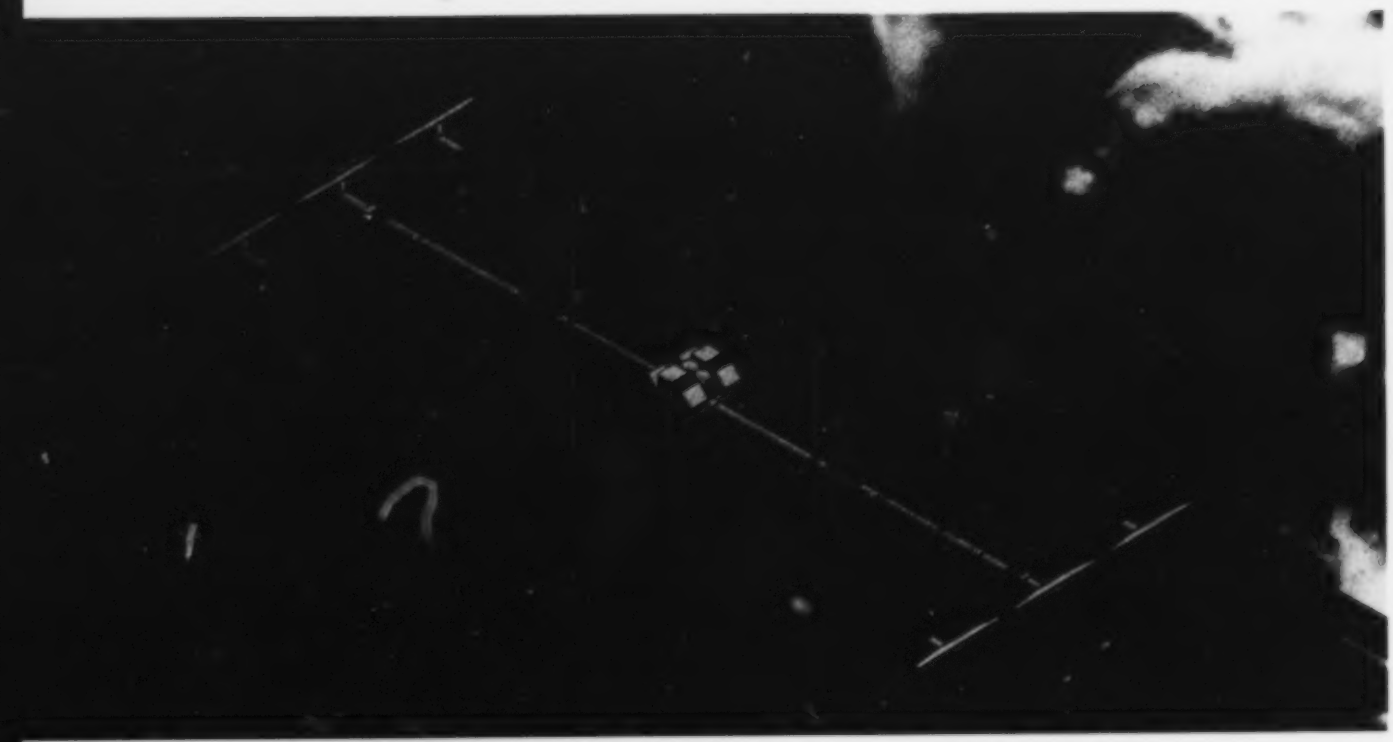
NASA has not yet determined what form the station might take, but is examining two reference concepts for a facility tended by the Space Shuttle. One, under study by Marshall Space Flight Center (MFSC), is the Space Platform concept; the other approach, being investigated by Johnson Space Center (JSC), is called the Space Operations Center (see page 18). Both concepts envision a step-by-step modular approach, beginning with a basic facility to which additional units could be attached to increase the utility and versatility of the station.

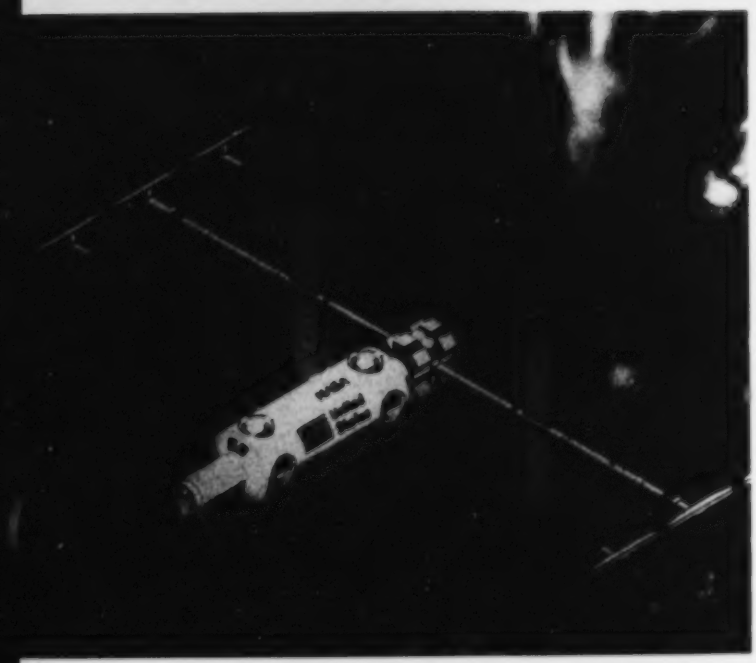
The accompanying artwork illustrates the MFSC Space Platform concept. The upper left photo on the opposite page shows an early step, an unmanned platform for long duration science and applications experiments. The core of the design is a rectangular main body (center) containing attitude control, data management and other systems for support of the payloads. Appended to the main body are the large solar arrays for electric power, an extendable radiator to dissipate heat generated by payloads, and a "reboost" propulsion system for changing altitude. The main body has five berthing ports, one of which permits docking the Shuttle Orbiter for maintenance operations; the others accommodate payload pallets. Three of the berthing ports have provisions for rotating the pallets to get the best viewing position for the payload. At lower left is an evolutionary step containing additional payload pallets and a larger solar array for increased power supply. At left, the platform becomes a manned station by addition of a habitable module and supplies for a crew of four. The photo below shows how the facility might evolve into a multi-pallet, multi-module space station handling several types of space operations.



Space Station (continued)

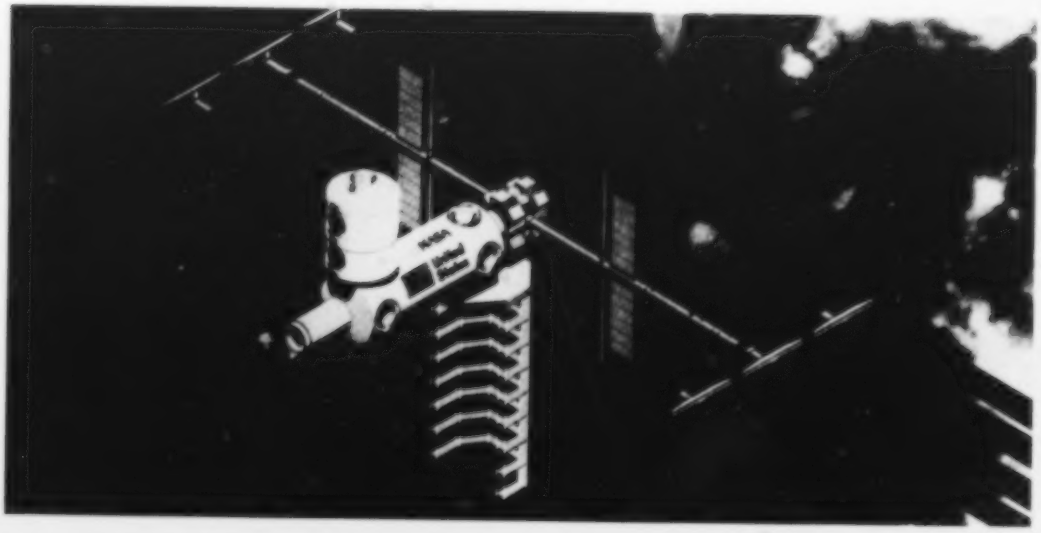
Where the Space Platform (page 16) would begin as an unmanned facility and evolve into a multipurpose station, the Space Operations Center (SOC) is designed for manned presence at the outset of orbital operations. Under study by Johnson Space Center, the SOC would be a base for science and applications experiments; for servicing unmanned satellites; for boosting payloads to higher orbit or sending them into interplanetary trajectories; for





assembly and deployment of large payloads that might otherwise require multiple Shuttle missions; or for erection of large space structures.

The illustrations show one possible evolutionary sequence, beginning with a basic Shuttle-deployed structure (above) consisting of a central berthing core in which Shuttle-delivered modules could dock; solar panels for electric power; a pair of antennas; and a set of radiators for thermal control. At left, a habitable module with living and working quarters for a crew of four is added; it has berthing ports for docking other modules.



The above photo shows the next step, connection of a hangar for storing and servicing a reusable Orbital Transfer Vehicle (OTV). Permanently space-based, the OTV would propel payloads to high-altitude orbits or start them on interplanetary missions, then return to its hangar to await another assignment; this would allow the Shuttle Orbiter to deliver only the payload on missions that would otherwise require it to bring along an upper stage launch vehicle. Shown below is a later growth version of the station, which might include such facilities as a scientific laboratory, a materials processing factory, a module for servicing payloads and another for fabrication of large space systems.

Toward Future Flight

NASA aeronautical research is providing new technology for coming generations of better performing, more efficient aircraft

Last year, the U.S. airlines burned some 10 billion gallons of jet fuel at an average cost of well above one dollar per gallon. If fuel consumption had been only five percent lower, the airlines could have converted a $300 million loss to a substantial profit.

This underlines the importance of NASA's Aircraft Energy Efficiency (ACEE) program, which aims at developing advanced technologies that could cut fuel consumption of new transports not just by five percent but perhaps as much as 50 percent. Many of the fuel-efficiency improvements already developed or contemplated are also applicable to the fleet of military transport aircraft. The ACEE program thus offers enormous potential for U.S. aviation energy conservation, with attendant benefit to the national economy in reduced oil imports, savings in defense operations, strengthening of the financially-buffeted airline industry, and enhanced attractiveness of U.S.-built aircraft in the international marketplace.

Instituted at Congressional request, the ACEE program is intended to provide U.S. transport manufacturers an inventory of fuel-saving technologies for improving current aircraft and developing advanced jetliner designs. ACEE is a comprehensive effort which addresses all of the major considerations in aircraft fuel expenditure—not only the propulsion system but also aerodynamics, structures, guidance and control. Some ACEE-developed technologies have already been incorporated in production aircraft, some are undergoing in-service evaluation aboard operational jetliners. In other instances, researchers have established promising approaches.

Much of the ACEE effort focuses on propulsion systems. One phase of the work deals with analysis of engine components to find out why parts deteriorate—causing reduced thrust and higher fuel consumption—and how components may be redesigned for longer effective life. Another phase is concerned with development of advanced component technology for a new generation of fuel-efficient turbofan engines. An area of propulsion research which offers particular promise is the advanced

This is a wind tunnel test model of an advanced turboprop featuring multiple swept-tip propeller blades. Research indicates that redesigned turboprops can drive transport aircraft at jetlike speeds with sharply reduced fuel consumption.

Shown undergoing evaluation aboard a McDonnell Douglas DC-10, NASA-developed winglets reduce drag and save fuel by smoothing air turbulence that builds up at the wingtips of a high speed airplane.

turboprop engine. The turbine-driven propeller has inherently better fuel consumption than the jet or turbofan engine but—in the days when fuel was a negligible factor—it lost favor in commercial aircraft design because it could not match the jet engine's ability to drive airliners at high subsonic speed. Research now indicates that new, multibladed, swept-tip turbine-driven propellers can provide jetliner speeds—with fuel savings of about 20 percent.

Aside from engine efficiency, another way of cutting fuel consumption is through aerodynamic improvements which reduce air resistance, hence ease the engine's workload. One example is the NASA-developed "supercritical" wing—actually a family of wings for different aircraft types—which is designed to delay the buildup of air drag that occurs at high speeds. Winglets, near-vertical extensions of the wing, also reduce air drag by lessening the effect of vortices, swirls of air that form at the wingtips.

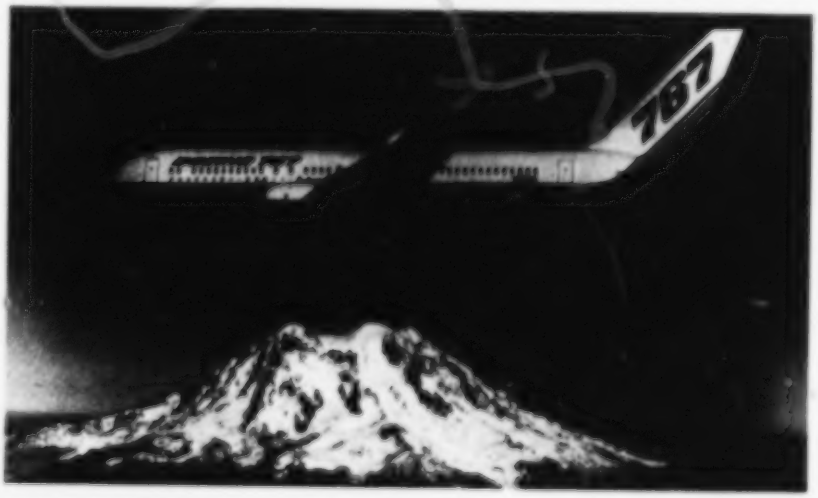
Obviously, a lighter airplane also eases engine workload. One part of the ACEE program seeks weight reductions by substitution of composite materials for conventional aircraft metal alloys. Composites are matrices of graphite, glass or man-made fibers; lighter but stronger than the metals they replace, they can reduce aircraft structural weight by 25 percent or more. Also under investigation are "active" controls, computerized systems which automatically smooth an airplane's flight, thus making it possible to design lighter structures without sacrificing safety.

Although ACEE's primary goal is reduced fuel consumption, the program offers a number of ancillary bonuses. For example, propulsion research is contributing to noise abatement and cleaner engine exhausts; composites research offers possible savings in the cost of fabricating structural components and active control research holds promise for improved passenger comfort during flight through turbulent air.

ACEE exemplifies one of two main avenues of NASA aeronautical research: generating technology for the solution of current and predictable aviation problems. Other examples include efforts to improve the air transportation system by finding ways to alleviate airport congestion and improve bad weather operations. Additionally, NASA conducts continuing investigations toward making airplanes safer, for example, research on atmospheric phenomena that affect flight, fire-resistant materials, collision avoidance, and improved structures for better passenger protection.

In the other avenue of research, NASA anticipates the longer range needs of future flight and develops applicable technology. This involves, on the one hand, research of a general nature aimed at advancing aerodynamics, propulsion, materials and structures, aviation electronics and knowledge of the human factors in flight operations. Additionally, it includes technology development for specific types of flight vehicles, such as tomorrow's general aviation planes, advanced rotorcraft and V/STOL (Vertical/Short Take-Off and Landing) aircraft, large cargo aircraft, high-performance military aircraft, and the better-performing, more economically viable, more environmentally acceptable commercial airliners that will be operating in the 1990s and beyond.

Lightweight composite materials offer fuel savings through reduced aircraft structural weight. The Boeing 767, which will enter airline service this year, is the first commercial jetliner to make extensive use of composites; their substitution for aluminum and fiberglass in 19 components saves an impressive 1,250 pounds per airplane.



Tilt Rotor Aircraft

A promising candidate for future civil and military applications is the tilt rotor transport, which combines the vertical lift, hover and maneuverability advantages of the helicopter with the greater forward speed of the fixed-wing airplane. Bell Helicopter Textron built two experimental XV-15 Tilt Rotor Research Aircraft for a NASA Army program intended to prove the concept and provide design information for later operational aircraft of this type. The XV-15 has helicopter-like rotors for vertical takeoff and landing (above); once airborne, the rotors tilt forward to become propellers for cruise flight (right).

The XV-15 can fly roughly twice as fast and twice as far as a helicopter on an equal amount of fuel; it has achieved a top speed of 346 miles per hour and reached 115 miles per hour in the helicopter mode. One of the two XV-15s has been returned to the manufacturer's plant for modifications; the other is undergoing a comprehensive flight test program jointly managed by Ames Research Center and the Army Aviation Research and Development Command.

Bell Helicopter Textron is studying advanced versions which would have three or four engines instead of the two engines in the experimental craft. Possibilities for civil air transportation include a 16-passenger corporate airplane and a 40-passenger commuter airliner capable of operating from small airports; the latter design would also have utility as a delivery aircraft for offshore oil facilities. Among military possibilities are a gunship with greater speed and endurance than the helicopters which now fill that role, and a troop transport which could shuttle from ships to forward combat areas where there are no runways.

Quiet Short-haul Jet

The airplane pictured is the Quiet Short-haul Research Aircraft (QSRA), an experimental craft which is demonstrating technology applicable to solution of two major aviation problems—airport congestion and aircraft noise. Built by Boeing Commercial Airplane Company and managed by Ames Research Center, the QSRA features an innovation known as "propulsive lift," in which engine exhaust is deflected downward over the wing surface to increase aircraft lift. This permits the QSRA to climb and descend at steep angles, fly safely at very low speeds, and operate from runways measuring only 1,500 to 4,000 feet, compared with the mile or more needed by conventional long-haul jetliners. These capabilities open up the possibility of flying advanced STOL (Short TakeOff and Landing) aircraft from separate, small, close-to-city airports, alleviating congestion at major "hub" terminals.

Since low noise levels would be essential to such operations, the QSRA project also addresses that consideration. The engines are soundproofed to muffle internal noise. External noise is also reduced by the fact that the engines are mounted above the wing; engine noise is thus blocked by the wing and diverted upward, away from the "eardrum" zone below. These factors, together with the plane's steep climb and descent characteristics, combine to demonstrate the potential for quiet, short-haul aircraft of the future.

A 1981 highlight of the QSRA program was a series of evaluation flights by 22 pilots from NASA, the Federal Aviation Administration, the military services, airlines and transport manufacturing companies. NASA conducted the pilot evaluation program to acquaint potential users with the technology and to get an independent critique of the QSRA's capabilities.

HiMAT

An important military aviation objective is development of high performance, highly maneuverable fighter aircraft which are smaller, lighter and less costly than currently operational types. A research effort aimed toward that objective is a NASA Air Force program—called HiMAT, for Highly Maneuverable Aircraft Technology—involving demonstration of a number of advancements such as new aerodynamic shapes, lightweight composite materials in the structure, and active electronic controls which allow greater flexibility in designing future aircraft configurations.

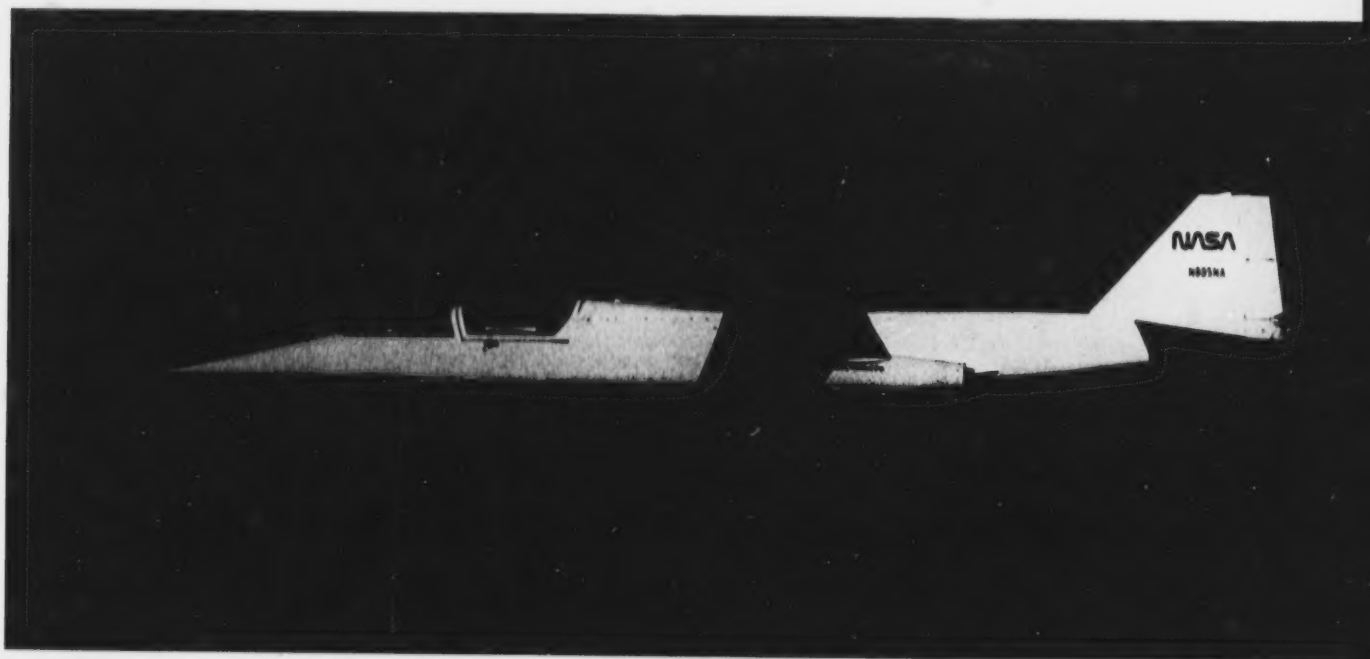
The HiMAT test craft shown, one of two built by Rockwell International, is an unmanned remotely piloted research vehicle which is air-launched from a B-52 carrier plane and "flown" by a pilot on the ground. This concept allows high-risk testing without risk to human life and also reduces vehicle costs normally associated with provisions for pilot occupancy and safety. Designed in modular fashion, HiMAT can be readily modified to incorporate new technologies as they come along.

The uniquely-shaped HiMAT pictured has a primary wing with tip-mounted winglets and a small forward "canard" wing, an airfoil combination that offers significantly increased maneuverability. The craft is approximately a half-scale model of a potential lightweight, low-cost future fighter.

Pivoting Wing

The AD-1 research airplane, whose wing can be pivoted in flight, was successfully flown during 1981 at various wing angles up to the maximum 60 degrees. This marked the culmination of a two-year program of testing the "oblique wing" concept that offers potentially greater aerodynamic efficiency at supersonic speeds with good efficiency and flying qualities at lower speeds. Future oblique wing aircraft would fly with the wing perpendicular to the fuselage to get maximum lift for takeoff, landing and low speed flight. At transonic and low supersonic speeds, the wing would be obliquely angled to decrease aerodynamic drag, or air resistance. Thus, compared with a fixed-wing airplane, the oblique wing craft could potentially fly faster or farther for the same fuel expenditure.

In its 38-flight program, the AD-1 flew only at low speeds; it was not designed for transonic supersonic flight since it was intended only to demonstrate the pivoting-wing capability and to study the handling qualities of an oblique wing aircraft. The "AD" stands for Ames/Dryden. Ames Research Center performed analytical and wind tunnel studies and the ARC Dryden Flight Research Facility conducted the flight tests.



Energy Absorption Tests

A goal of NASA Federal Aviation Administration (FAA) safety research is to give occupants of light, general aviation aircraft a better chance of survival if the plane crashes. One aspect of that work, illustrated by the accompanying photos, involves tests at Langley Research Center of a "crushable" aircraft subfloor designed to absorb some of the energy of a crash impact and thereby reduce the crash forces transmitted to passengers.

The test article at upper left simulates the interior floor and subfloor of a lightplane before an impact test; the lead-weighted red structures represent the equivalent mass of two seats and their occupants. The lower photo shows the test rig after it had been hoisted to a height of nine feet and dropped to simulate crash impact. The subfloor, made of collapsible parts, is crushed, but the "crush zone" it provided absorbed sufficient impact energy to leave the floor and seats undamaged.

In future tests at Langley, energy-absorbing subfloor designs will be tested in full-scale crashes of lightplanes dropped from 200 feet to impact at 75–80 miles per hour. Related work under way is aimed at improving the energy absorption characteristics of aircraft seats and restraint systems. Various seat concepts are being studied at Langley and at the FAA's Civil Air Medical Institute, Oklahoma City, Oklahoma.

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Lightning Research

Lightning *can* strike the same object twice—or more—researchers from Langley Research Center have found. In tests at the National Severe Storms Laboratory in Oklahoma, the airplane pictured was struck three times as it was intentionally flown through severe thunderstorms. The airplane is a General Dynamics F-106B military fighter modified for research work; it carries within its fuselage a package of instruments for recording lightning strikes and acquiring other atmospheric chemistry data. There exists considerable information about lightning, but most of it resulted from ground level studies. The Langley work focuses on how lightning affects aircraft in flight and how future aircraft may be protected from lightning effect. The F-106B flights are part of a broader program of storm hazard research, which includes studies of air turbulence, wind shear—sudden changes in wind velocity or direction—and other safety aspects of flight in severe storms.

Dividends from Technology Applied

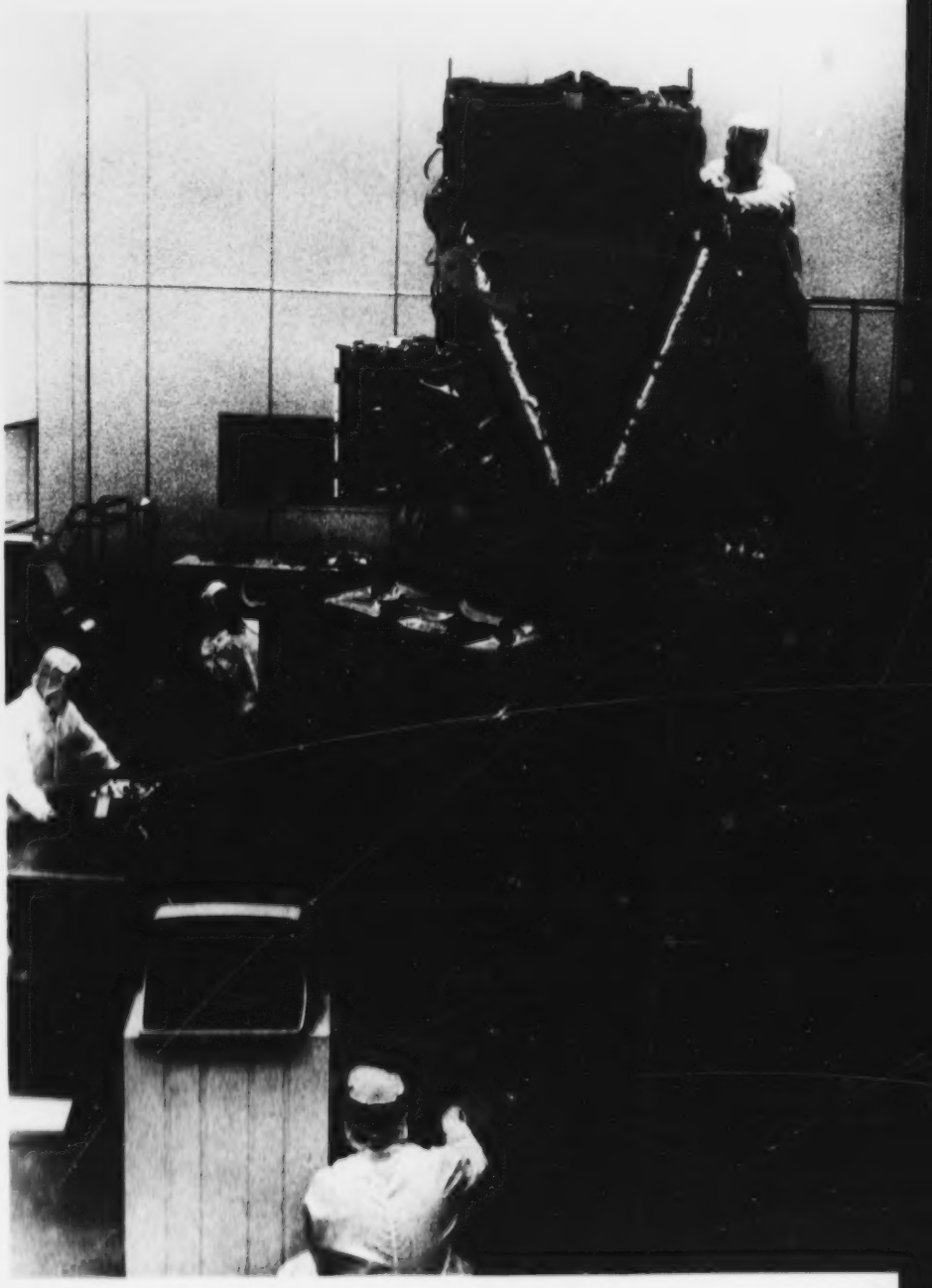
NASA's applications program employs aerospace science and technology to provide direct public benefit

This year marks the 10th anniversary of a NASA program for collecting voluminous information about Earth's resources by means of remote sensing instruments on a platform in space. The first such platform was the Landsat 1 satellite, launched July 23, 1972; it was followed into orbit by Landsat 2 (1975) and Landsat 3 (1978), both still in service. These satellites have provided a foundation for what will someday be a global Earth survey system of enormous value in more effective management of the planet's resources.

Over the decade, the Landsat system has matured considerably as regards spacecraft instrumentation and ground processing techniques for extracting useful information from the satellites' signals. Many demonstrations of its potential have attracted a widening circle of users in the U.S. and abroad. About a dozen nations now have their own capabilities for receiving and processing data directly from the satellites, and more than 100 nations are using Landsat imagery for such purposes as agricultural inventory, oil and mineral exploration, water management, land use planning, forestry operations, mapmaking and a broad variety of other applications.

NASA will observe the 10th anniversary by sending into orbit a new and more advanced member of the Landsat family. Known as Landsat-D—Landsat 4 after it is launched—it incorporates many improvements based on a decade's experience with its predecessors and will significantly upgrade the system's capability.

The Landsat system offers several major advantages as a tool for Earth resources monitoring. The individual satellite scans the entire Earth—except for the polar regions—every 16 to 18 days, and a single Landsat view embraces an area larger than the state of Maryland.



making it possible to observe great Earth features, such as geologic faults, that are impossible to see from near-Earth. Repetitive coverage allows monitoring of Earth processes that change with time, such as crop growing or land use patterns. And Landsat acquires information not only in the visible wavelengths, but in parts of the spectrum that are invisible to the human eye or to ordinary cameras.

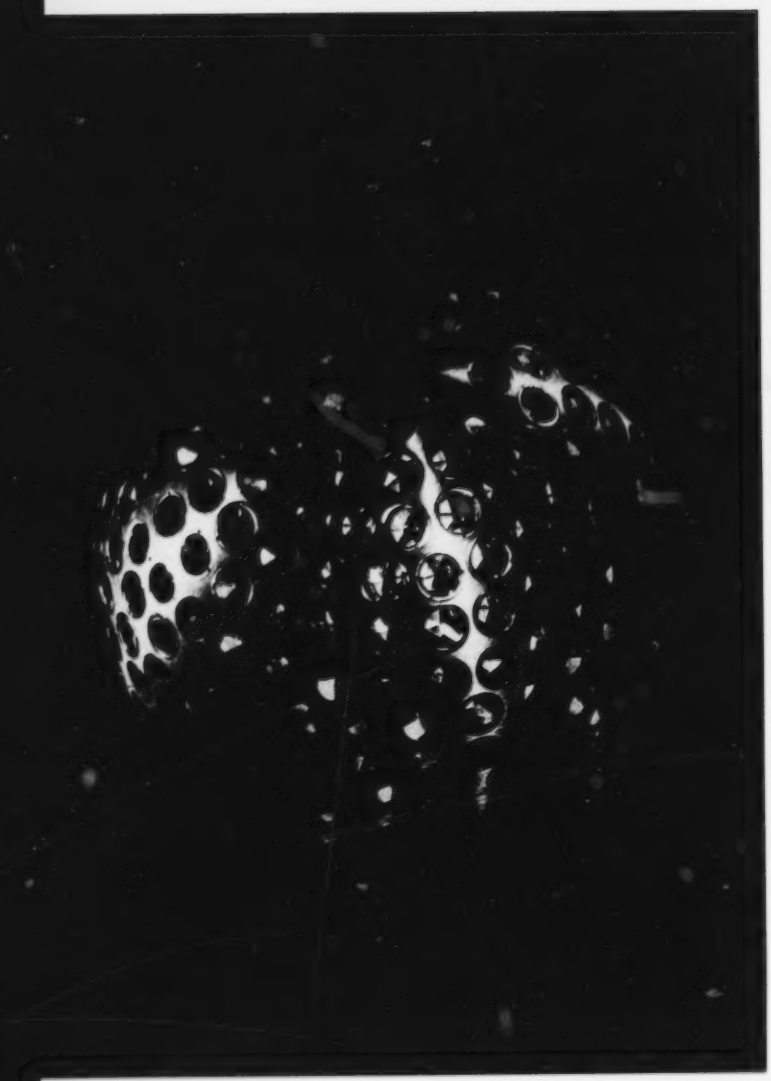
In the first three Landsats, the principal instrument is the multispectral scanner (MSS), which employs an Earth-viewing telescope and bands of radiation detectors to pick up light and heat waves emanating from Earth objects. Since each type of object has its own unique radiation "signature," Landsat offers a means of producing electronic pictures of Earth in which specific features of importance to resources managers are identified. The MSS detectors separate the radiations reflected from Earth into four spectral bands, two in visible light and two in the invisible near-infrared; the light in each band is further classified according to brightness. All this information is converted to digital signals, transmitted to ground stations at the rate of 15 million "bits" per second, and there computer-processed into highly informative tapes and images which show, for example, color-coded differences between one type of vegetation and another, between healthy and diseased crops, clear and polluted water, urban or farmland or wilderness areas, and scores of other classifications.

What makes Landsat-D important is that it is equipped not only with the MSS and other instruments aboard the earlier Landsats, it also has a new and highly advanced scanning system called the Thematic Mapper (TM). The TM operates in much the same manner as the MSS, with the very significant differences that it collects data in seven spectral bands (compared with the MSS' four) and provides resolution, or clarity of detail, almost three times better than the MSS. These and other advantages will open up a new range of applications that could be accomplished only marginally or not at all with the predecessor Landsats.

Built by General Electric Company's Space Systems Division, Valley Forge, Pennsylvania, Landsat-D is slated for launch late this year. In the wings is a companion spacecraft, known as Landsat-D Prime, which could be sent into orbit next year if needed but will probably be maintained as a backup until mid-decade. The Landsat program is managed by Goddard Space Flight Center.

Landsat is one of the major elements of what NASA calls its Applications Program, which has the aim of generating public benefit through direct application of aerospace technology to societal needs. Other types of applications spacecraft include systems for weather, climate, air quality and other environmental observations; advanced communications systems; and satellites for geodynamics research and for study of ocean processes. A relatively new applications area is investigation of processing materials in orbit, a step toward future manufacture of items better produced in the weightless environment or not at all producible under conditions of Earth gravity. NASA also conducts applications projects of a non-space nature, employing ground-based or airborne systems to solve major problems or meet important civil needs.

On the opposite page, the Landsat-D satellite is undergoing tests in a clean room facility at General Electric Company's Space Systems Division. Weighing more than two tons, it is an advanced member of the Landsat family of Earth resources monitoring satellites in service for a decade. At left, Landsat-D is pictured as it will look in orbit, with its antenna and solar cell array extended.



Earth Crustal Study

Earth's crust is composed of a series of large land masses known as "tectonic plates" that are constantly in motion, often grinding against each other, sometimes causing surface deformations and earthquakes. Current knowledge, largely theoretical, estimates relative motion of the tectonic plates at one to 20 centimeters (eight inches) a year. A NASA Crustal Dynamics Project involving 56 U.S. and foreign investigators seeks more precise information about plate movement, crustal deformation and other aspects of Earth's dynamic behavior—which, in turn, is expected to provide better understanding of the mechanisms that produce earthquakes. The program is managed by Goddard Space Flight Center, with participation by Jet Propulsion Laboratory; it will continue through 1986.

As a means of monitoring crustal motion, NASA has developed two different techniques for making precise measurements between two points on Earth thousands of miles apart. One, called laser ranging, employs the Lageos satellite pictured. Lageos has 426 optical reflectors which "bounce" back to the source a laser pulse beamed from an Earth station. Repeated measurement of the time it takes the pulse to travel to the satellite and return allows high-accuracy determination of the ground station's position. When similar measurements are made from a second station, the distance between the two stations can be determined within two inches.

The second technique, called Very Long Baseline Interferometry (VLBI), involves analysis of signals emitted by quasars or other celestial sources, picked up and recorded by two or more Earth-based radiotelescopes. Comparison of the times the signals reached each telescope enables measurement of the distance between them with an accuracy better than an inch and a half. By making repeated measurements over a period of years, using either the laser ranging or VLBI technique, scientists can tell how far the Earth stations moved from each other, hence determine average crustal motions as small as one centimeter a year.

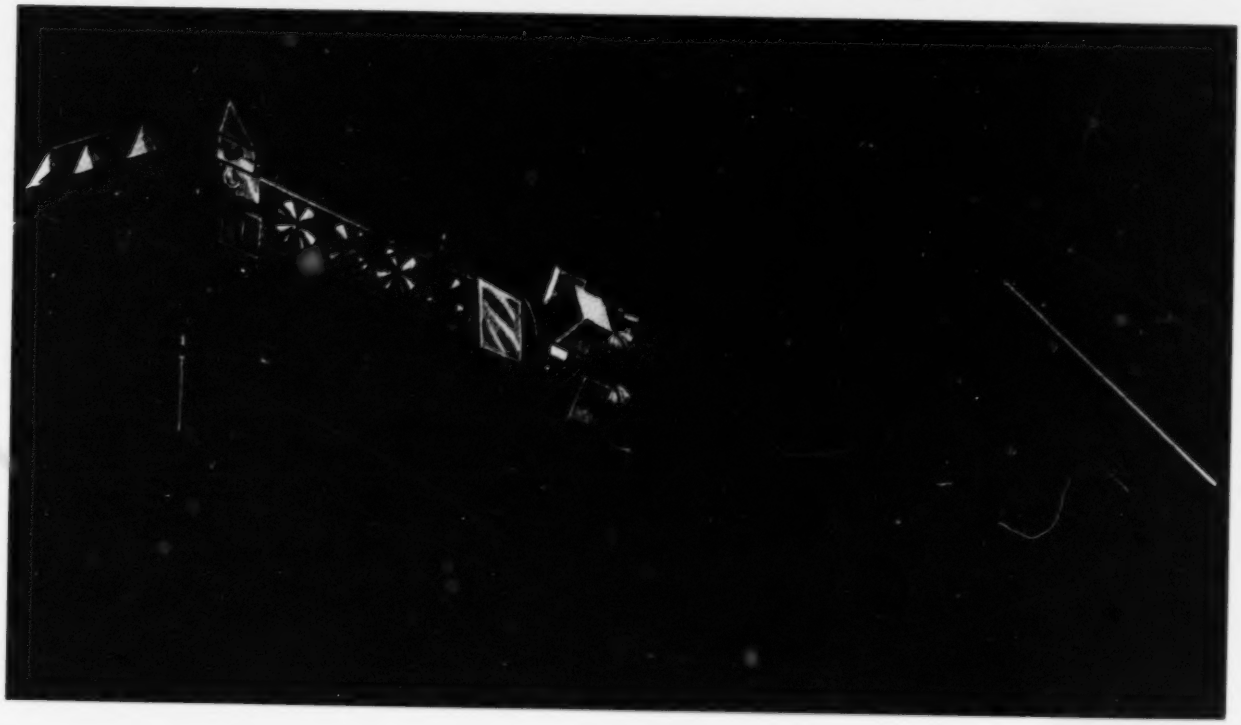
Plate movement causes buildup of crustal strain near plate boundaries; earthquakes occur when the resulting stress exceeds the strength of the underlying materials. A major project objective is measurement of strain accumulation along major plate boundaries, which may lead to development of a reliable earthquake prediction model. Since measurements must be made at a great many sites, NASA has developed mobile systems—for either laser ranging or VLBI—that can be relocated in a matter of days.

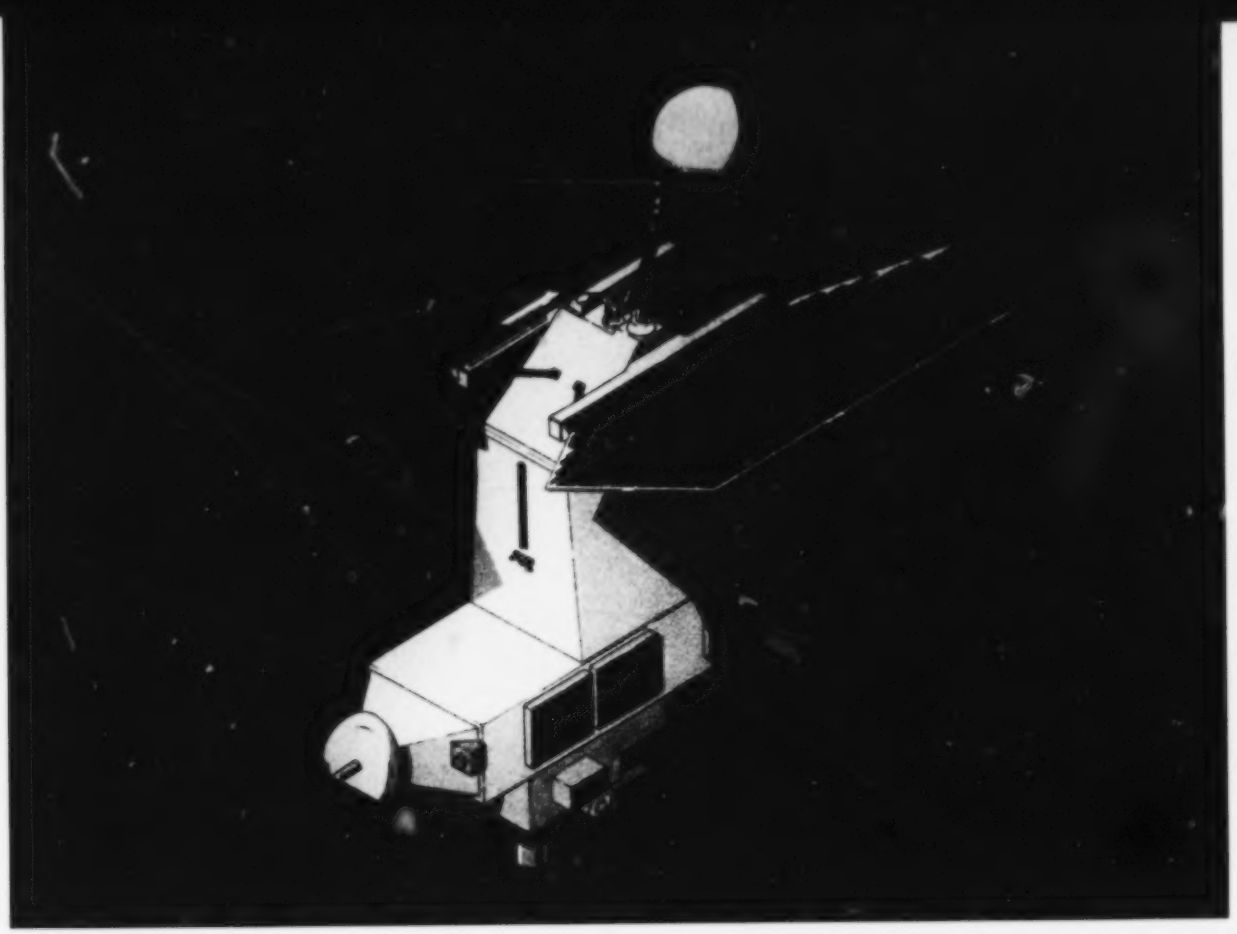
Search and Rescue System

Ships and aircraft carry radio beacons to signal an emergency and provide a homing beam for locating the position of the craft in distress. These beacons are often useful in search and rescue operations, but their effectiveness is limited by lack of *continuous* signal monitoring and by frequently-encountered difficulties in tracing the signal source. To meet the need for a better means of detecting and locating signals from downed aircraft or troubled ships—and thereby greatly increase the probability of saving lives—the United States, Canada, France and the Soviet Union have embarked on development of a global satellite-based search and rescue system.

In collaboration with French and Canadian agencies and the U.S. Air Force, Coast Guard and National Oceanic and Atmospheric Administration (NOAA), NASA is developing an equipment package to be carried aboard operational satellites of the NOAA environment monitoring network (below). Called SARSAT—for Satellite-aided Search and Rescue System—it will monitor distress signals from either existing types of beacons or a new, specially-designed beacon being developed. The Soviet Union is working independently on a similar system called COSPAS, which is compatible with SARSAT.

SARSAT COSPAS satellites will "listen" continuously on emergency frequencies used by ships and aircraft. When the spaceborne equipment package picks up a beacon alert, it will relay the signal to a ground-based Local User Terminal. Within minutes, a computer will produce a position "fix," locating the emergency site within three miles if the troubled craft is equipped with the special beacon, 12 miles if it has an existing beacon. Rescue coordination centers will be notified that an emergency has occurred and advised of the whereabouts for guidance of search and rescue craft. A demonstration of the experimental system will begin this year; if successful, it could lead to establishment of an international operational system which, in addition to its life-saving potential, could allow substantial reduction in the costs of search and rescue operations.





Radiation Measurement

Some parts of Earth absorb more energy from the Sun than do others, and some parts radiate more heat energy back to space than do others; thus, Earth's surface is unevenly heated. Since air and water tend to move from warmer to cooler areas, this heating differential sets wind and ocean currents in motion; therefore, Earth's "radiation budget," as the differential is known, is a driving force for weather. Some basic information about the radiation budget has been provided by instruments aboard experimental satellites. However, more comprehensive data is needed to improve weather prediction and to anticipate climate trends which have major influence on planning in such areas as agriculture, energy, natural resources, transportation and construction.

For better understanding of the Sun-Earth radiation balance, NASA and the National Oceanic and Atmospheric Administration (NOAA) are planning an extensive investigation involving three spacecraft equipped with radiometers, instruments capable of measuring the amounts of radiation received and the amounts given up by different regions of Earth. NASA is developing an Earth Radiation Budget Experiment satellite (above), which is being designed and built by Ball Aerospace Systems Division of Ball Corporation, Boulder, Colorado. To be launched in 1984, the satellite will make possible the first global, "round-the-clock" radiation budget measurements. Its findings will be complemented by NOAA-F and NOAA-G, two new satellites of NOAA's operational space meteorological network, which will be equipped with radiometers in addition to their regular environment-sensing instrumentation. NOAA-F will be launched next year; NOAA-G is scheduled for orbital service in 1985.

Upper Atmosphere Research

Earth is continually bombarded by radiation from the Sun. However, much of this radiation is absorbed by Earth's upper atmosphere, where the radiation energy drives a complex chain of chemical reactions that both creates and destroys ozone. In recent years, man has become much more aware of the vital importance of the layer of ozone and much more concerned about the impact of human activities on atmospheric ozone: scientists believe that deterioration of the protective ozone "screen" might release a rain of harmful solar rays and energetic particles that could prove lethal to plants and animals and cause global climatic changes.

For more than a decade, in sounding rockets, balloons and satellites, NASA has been conducting an Upper Atmosphere Research program aimed toward a more thorough understanding of the atmospheric changes that influence Earth's environment and, in particular, the various factors involved in the formation and destruction of ozone. A wealth of data has been acquired, but the information simply underlines the extraordinary complexity of the upper atmosphere and emphasizes a requirement for a more comprehensive investigation. There is little concrete knowledge of how the various constituents of the atmosphere are transported, how they interact with each other, and what limits the results of these interactions. Also, there is some uncertainty as to the extent that human activities affect the ozone layer, hence a need for much more information so that scientists can ultimately predict with confidence the effects of man's actions on this vital component of the atmosphere.

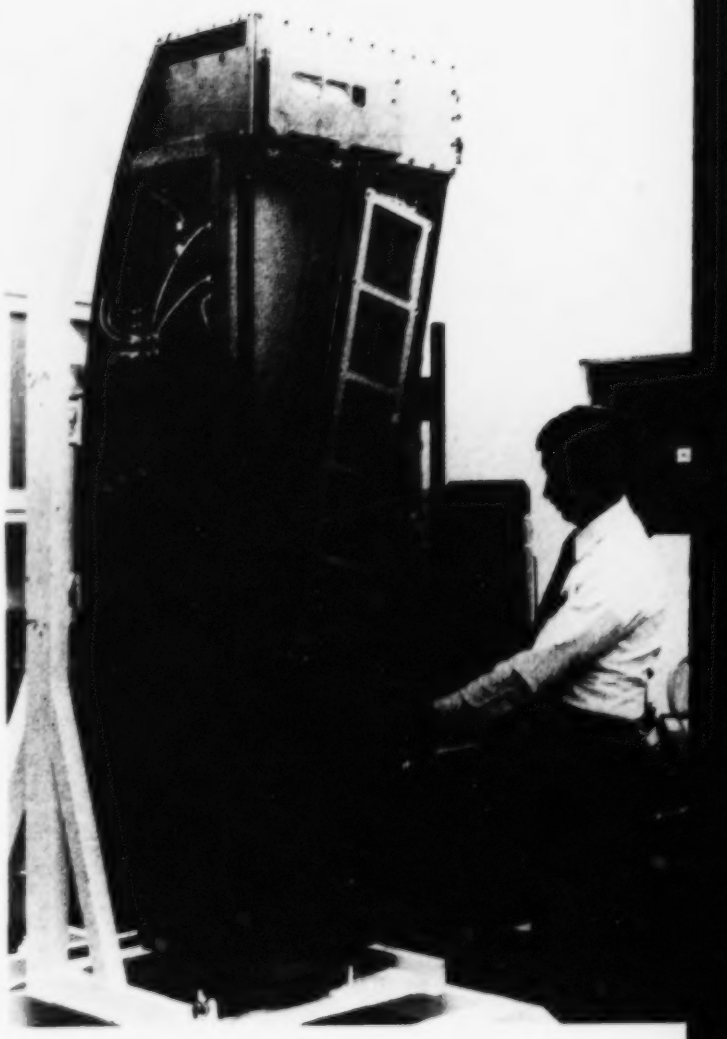
An interim step in studying ozone concentrations is the Solar Mesosphere Explorer launched last year (see page 44). The next major step contemplated is an advanced satellite system capable of simultaneous collection of data regarding the Sun's energy input, the chemistry and the dynamics of the upper atmosphere. NASA is developing experiments and instrumentation for a planned Upper Atmosphere Research Satellite (below), which could be available for orbital service in the late 1980s. The plan calls for development of two satellites, to be launched about a year apart to prevent long gaps in taking global ozone measurements.

Space Materials Processing

Earth's gravity exerts a number of adverse influences in manufacturing operations, for example, it prevents mixing of certain metallic combinations, induces impurities and limits output in preparation of pharmaceuticals. In the near-zero gravity of space—"microgravity," it is called—these and other adverse influences can be greatly reduced or eliminated. Thus, the advent of the Space Shuttle, whose Spacelab component—provided by the European Space Agency—offers utility as an experimental space materials processing facility, opens up possibilities for a new range of products that cannot be processed on Earth—superior metal alloys for construction and manufacturing use; pure glass, free of container contamination, for laser and optical use; flawless crystals for improved electronic systems; and an entirely new class of high-purity pharmaceuticals for more effective treatment of disease. A Materials Experiment Assembly being developed for use aboard the Shuttle Orbiter will allow microgravity experiment time of several hours, where earlier research—in ground-based drop tubes, aircraft or sounding rockets—was limited to periods ranging from a few seconds to five minutes.

NASA plans a number of materials processing experiments separately and in conjunction with industry under a "joint endeavor" program, in which NASA and the industrial firm each provide funding for their own portions of a cooperative project. In the first such experiment, McDonnell Douglas Astronautics Company, St. Louis, Missouri will conduct Shuttleborne investigations involving separation of materials in solution under microgravity, an initial step toward development of a space-based system for producing high-purity pharmaceuticals in large quantities; the experimental unit is shown at right. In another project, NASA will cooperate with GTI Corporation, San Diego, California in testing the behavior of various metal alloys under the weightless conditions of orbital flight; GTI will develop an alloy solidification furnace system to be flown aboard the Space Shuttle.

NASA has also signed an agreement with Deere and Company, Moline, Illinois for a similar study of alloy processing in microgravity. Under the agreement, Marshall Space Flight Center will use non-orbiting facilities—drop tubes and aircraft, possibly sounding rockets—for experiments in which Deere-provided alloy samples will be melted and solidified under reduced gravity conditions. These experiments could lead to Deere's later participation in orbital tests. Several other commercial firms are discussing agreements with NASA.



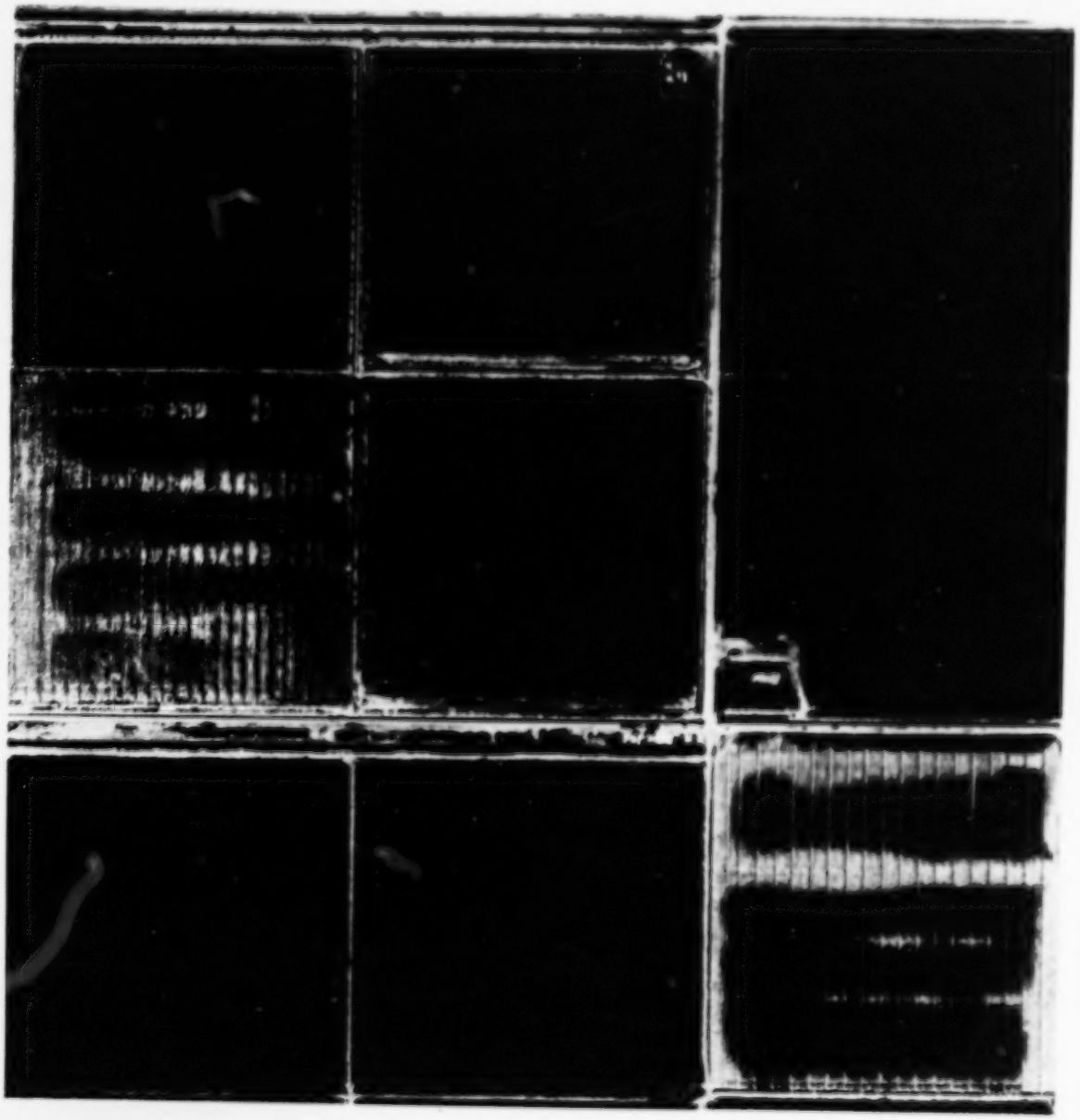
Farm Drainage Study

Using California's Imperial Valley as a test site, researchers from NASA and the U.S. Department of Agriculture conducted 1980–81 aerial photography experiments in an effort to develop techniques for spotting clogged underground drainage lines. An effective method for detecting clogging would be of great value in improving farm productivity, not only in the U.S. but also in Europe, where farmers rely on similar drainage systems.

In Imperial Valley, drainage lines six feet below the surface control the water table at root level and also flush away salts deposited by evaporated water. When the lines become clogged, the resulting salt buildup can damage crops. Drains can be unclogged by high pressure jet cleaning devices, but the problem is pinpointing the location of a clogged line early enough to save the crop.

The NASA/USDA experimental technique involves use of color infrared photography to find clog spots. Over a period of nine months, Ames Research Center aircraft photographed the same drainage area on a number of occasions at various times in the crop-growing cycle—bare soil, early growth and maximum growth. By comparing the photographs, scientists can detect a pattern of evidence, exemplified by the series of farm images below. Note that the middle left field has dried in an even pattern of white streaks after irrigation, while the one at bottom right dried unevenly. The latter photo suggests clogging and the field should be inspected.

Since last fall, project scientists have been analyzing data from the photographic flights to resolve such questions as how often should an aerial survey be conducted, at what period in the growing cycle should the survey be made, what time of day and what altitude is best for surveying, and whether infrared photography or some alternative system is the best sensing method. When these questions are answered, NASA and the USDA will turn the technique and related information over to private aerial photography firms that can be commissioned by local farm groups.



Exploring the Universe

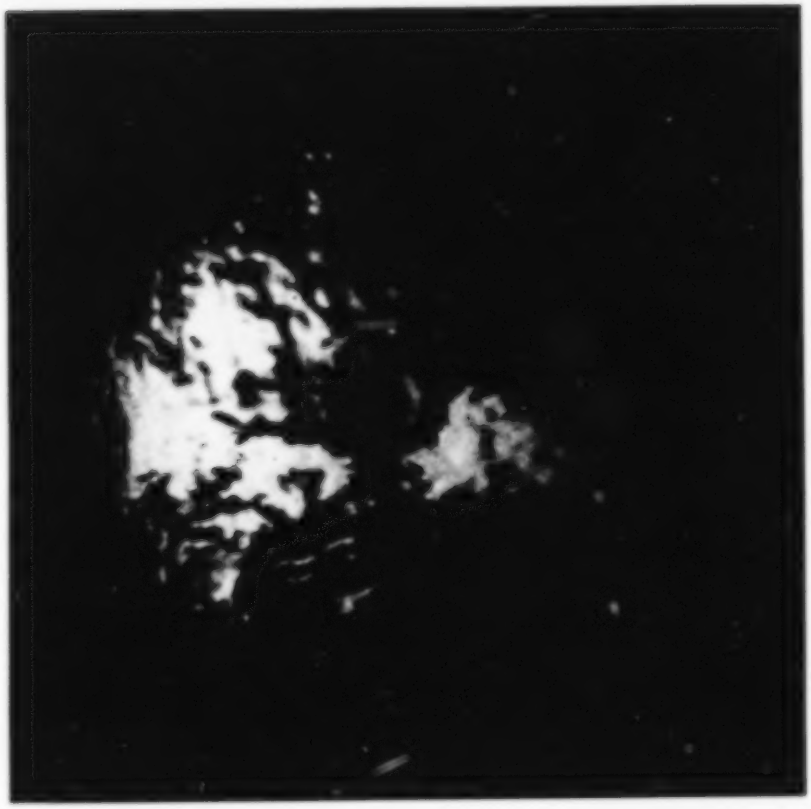
Space scientists are learning more about Earth by probing the solar system and the distant galaxies beyond

Our nearest planetary neighbor, cloud-shrouded Venus, approximates Earth in age, size, mass, density and orbital distance from the Sun. Yet in water content, atmosphere, temperature, pressure and many other aspects the two planets are markedly different.

Why, scientists want to know, did two similar planets evolve in such dissimilar fashion? Their interest stems from more than academic curiosity. They feel that the answers hold clues to greater understanding of the many factors that influence Earth's complex environment.

They don't yet have the answers, but they have moved closer to the goal, thanks to the Pioneer Venus project managed by Ames Research Center. For more than three years, the Pioneer Venus Orbiter has been circling Venus, studying its atmosphere, taking hundreds of ultraviolet pictures of its dense clouds, and radar-mapping its never-seen surface. Meanwhile, scientists have been analyzing complementary data from five Pioneer Venus probes, which descended by parachute through the planet's atmosphere. Although they operated for only an hour, they provided volumes of information, such as temperatures and pressures at various levels, atmospheric composition, wind forces and other elements of Venus' weather system.

From the findings of Pioneer Venus and earlier spacecraft, scientists have assembled a fascinating picture of mysterious Venus. The planet's atmosphere is almost entirely carbon dioxide and it exerts a pressure at the surface 100 times greater than Earth's. Surface temperature is about 900 degrees Fahrenheit, hot enough to melt lead. Surface temperature and pressure are about the same everywhere—at the equator, at the poles, on the day side and the night side. This is due to the "mixed" atmosphere, which not only circulates around the planet—as on Earth—but also from the equator to the poles. The planet rotates "backward"—east to west, the reverse of Earth's rotation; thus, the winds blow east to west and at velocities far greater than on Earth, up to 225 miles per hour at high altitudes.



Stripped of its permanent cloud cover, Venus might look like this computer-processed false color image in which blue represents lowlands, green medium elevations and yellow highlands. The global representation was prepared from data acquired by the Pioneer Venus Orbiter spacecraft.

Pioneer Venus provided the first real look at Venus topography. Prior to Pioneer, less than one percent of the surface had been measured; the spacecraft's radar has covered 93 percent. Maps prepared by the U.S. Geological Survey from Pioneer data show that 60 percent of the surface is relatively flat, rolling plain, varying in height by only about 300 feet.

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The contour map of Venus at left, based on data from the Pioneer Venus radar mapper, covers about 80 percent of the planet's surface, most of which (shown in blue and light blue) is flat plainland; highlands are shown in yellow. At top center is the highest of the highlands, a region known as Ishtar Terra which is about the size of the continental United States. At bottom right is an artist's conception of Ishtar Terra; at far right is Venus' tallest mountain peak, a mile higher than Everest.

Venus has no oceans, but some 16 percent of its surface is below a reference point that corresponds to Earth's sea level. The remaining 24 percent is highland area. The largest of the highland regions is half as large as Africa, another is about the size of the continental U.S. The latter has a mountain massif whose highest point is more than a mile higher than Earth's Everest.

A particularly important Pioneer Venus contribution was confirmation that Venus' searing surface temperature is due to a "greenhouse" effect, in which the Sun's heat and infrared light easily penetrate the atmosphere but cannot easily escape; trapped by the carbon dioxide, they cause rising temperatures. This is an area of Earth/Venus comparison of particular interest and concern, because 20th century burning of fossil fuels has raised Earth's own atmospheric carbon dioxide by 15 percent. Predictions hold that it could double in 50 years, with possible severe adverse impact on agriculture and food supply.

Although scientists can now study Venus from a new informational plateau, much remains to be learned. The Pioneer Venus Orbiter will contribute further; it will continue to report data through 1985, changing its orbital path to observe the planet from many new vantage points. In planning status is a new Venus explorer with advanced scientific instruments and a radar mapper that will provide resolution—clarity of detail—20 times better than Pioneer Venus.

Venus studies exemplify one aspect of NASA's four-pronged space science program: solar system exploration, or investigation of the planets, moons and other phenomena within our solar system. The other areas of activity include astrophysics, or the study of distant stars and galaxies; solar terrestrial research, study of the Sun's energy processes and their interactions with Earth's environment; and life sciences research, aimed at understanding the origin and distribution of life in the universe, and at utilizing the space environment to improve knowledge in medicine and biology.

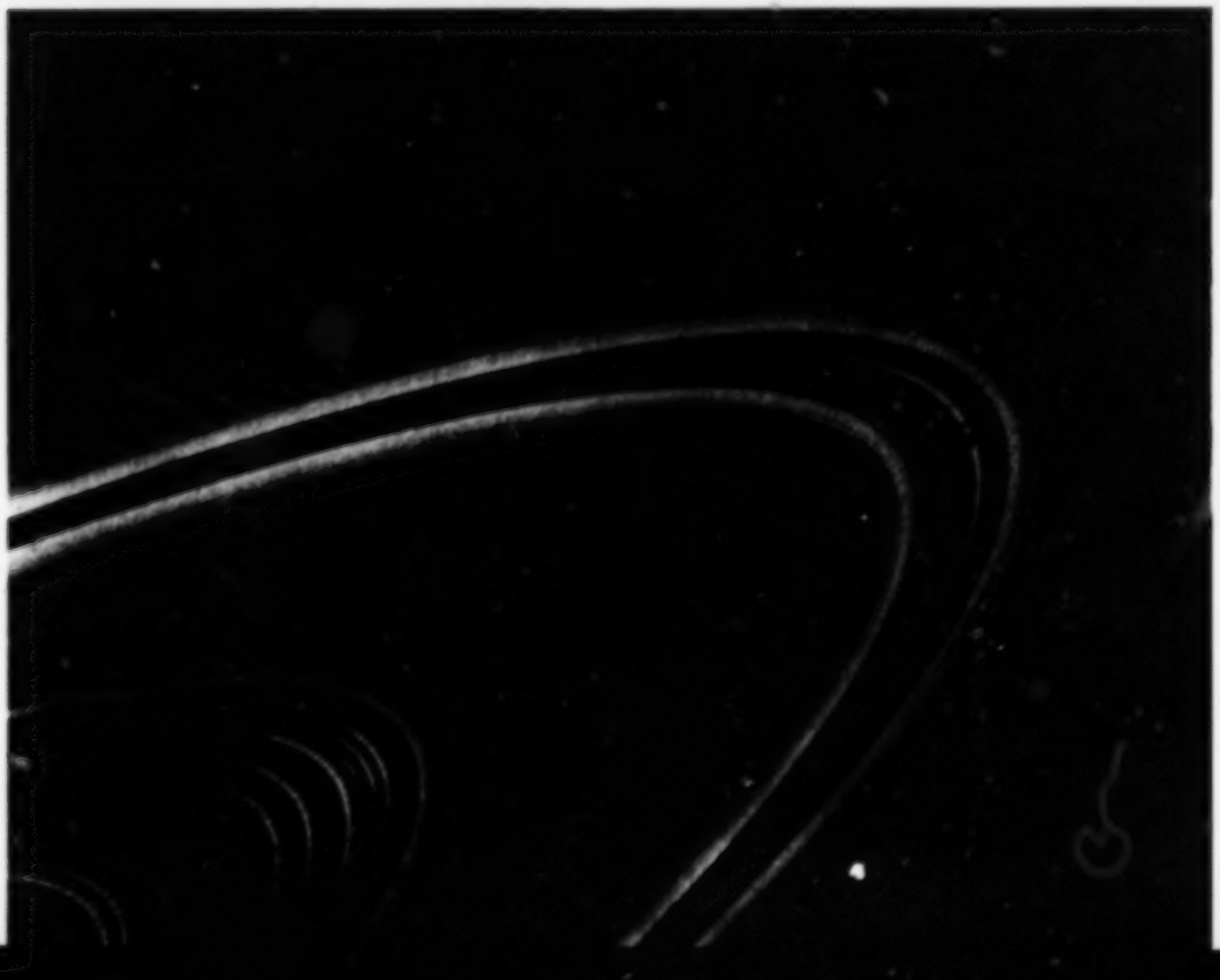
The essential goal of this comprehensive effort is fitting Earth into the cosmic picture—the origin, history and structure of the universe—and thus learning more about our own planet and the complex forces that control it. The end product is knowledge, a base for tomorrow's technology and a step toward the day when mankind may learn enough about nature's forces to manage them for sweeping benefits not imaginable today.

Voyager at Saturn

In 1981, NASA concluded a two-part reconnaissance of Saturn with the August visit to the ringed planet of the Voyager 2 spacecraft. Flying a different trajectory than did Voyager 1 on its 1980 Saturn encounter, Voyager 2 confirmed many of its predecessor's findings and provided volumes of new data. A major Voyager 2 discovery was a region surrounding Saturn that contains the hottest gas yet found in the solar system; the spacecraft's instruments indicated that temperatures range from 600 million to more than one billion degrees Fahrenheit, about 330 times hotter than the Sun's corona.

Like Voyager 1, Voyager 2 concentrated much of its imaging work on the Saturnian rings. In the image at left, taken from a distance of eight million miles, the rings appear to be a single solid band. The image below, taken from 5.5 million miles, clearly shows several ring systems composed of hundreds of individual "ringlets"; in this computer-enhanced view, the different colors represent variations in the chemical composition of the rings. At right is a close view of one of the ribbonlike white bands that girdle the planet; a high speed jetstream within the ribbon is moving at more than 300 miles per hour. Moving still closer to Saturn, Voyager 2 took the image at bottom right from a range of 393,000 miles. It is a view of the north polar region; the two oval "eyes" at right center are storm systems, each measuring about 150 miles across.

Voyager 2 also produced a great amount of new information about Saturn's moons. Of particular interest are the observations of Phoebe and Hyperion. Images



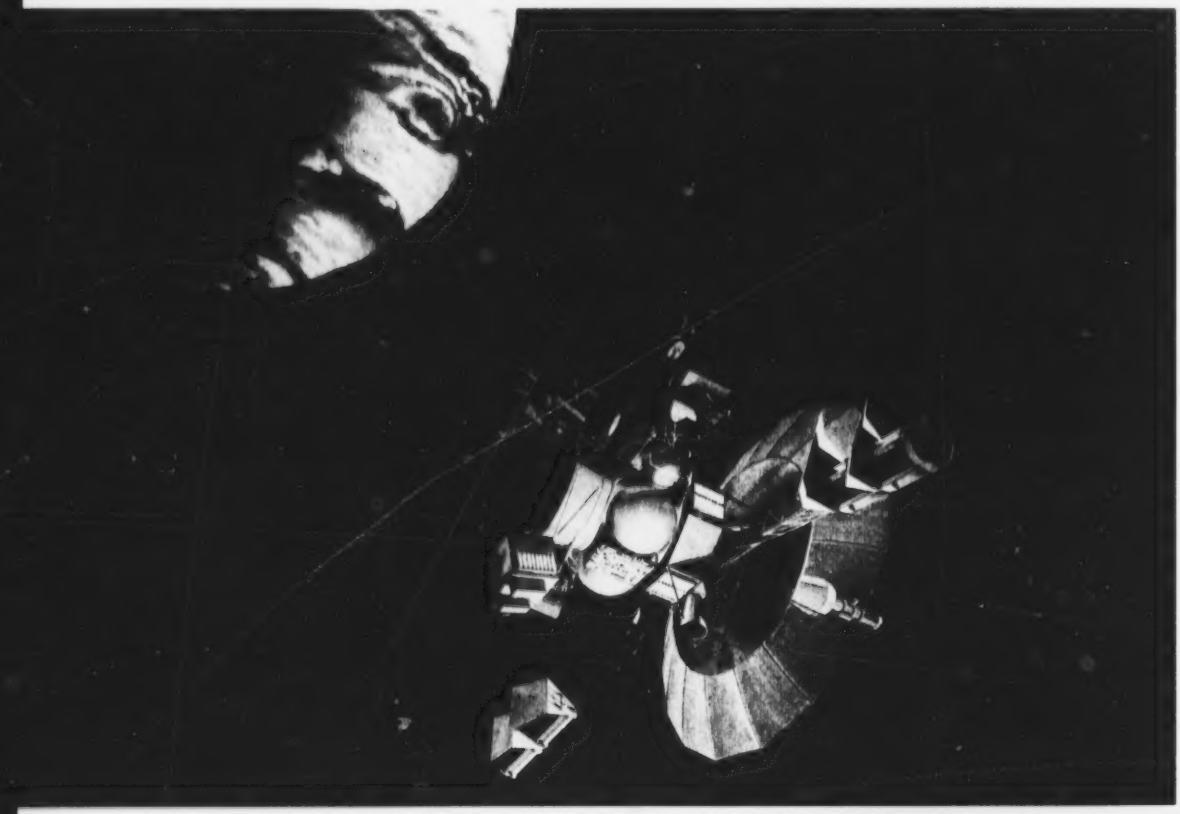
and instrument data indicate that Phoebe, the smallest and most distant moon, is rotating in the opposite direction from the other 16 known moons; some scientists believe it is a comet trapped by Saturn's great gravitational pull. Hyperion (upper right) is not ball-shaped like the other moons; images taken from different angles show slightly different shapes. A possible explanation is that Hyperion is wobbling in its orbit, still staggering from the impact of a long-ago collision that took away a big part of the moon and left it shaped like a potato.

Voyager 2 added more than 18,000 Saturn photos to a similar number taken by Voyager 1. With the conclusion of its Saturn investigation, Voyager 2 continued on a path that will take it to a 1986 encounter with Uranus, the seventh planet from the Sun, and a 1989 rendezvous with Neptune, the eighth planet. Neither has been visited by spacecraft. NASA's manager for the Voyager project is Jet Propulsion Laboratory.

Advanced Jupiter Exploration

The giant gas planet Jupiter has been visited four times by survey spacecraft—Pioneers 10 and 11 in 1973-74 and Voyagers 1 and 2 in 1979. These missions enormously expanded knowledge of Jupiter and understanding of the solar system. But the information they provided was obtained during relatively brief fly-by encounters. There remains a need for long-term detailed studies of the entire Jupiter system. NASA plans to meet that need with the Galileo mission, which includes a Jupiter-orbiting observatory (below) and the first entry probe into the planet's atmosphere (bottom right).

To be launched in 1985, Galileo will reach Jupiter some 30 months later. The probe, designed by Ames Research Center and built by General Electric Company's Space Division, will descend into the Jovian atmosphere, protected by a heat shield from temperatures expected to reach 14,000 degrees Fahrenheit. Its seven instruments, lowered by parachute, will investigate the composition of the atmosphere for about one hour. The orbiter spacecraft will become a man-made moon of Jupiter, providing long-term imaging and remote sensing measurements of the planet and its moons. Galileo is a cooperative project with the Federal Republic of Germany. Jet Propulsion Laboratory is project manager and builder of the orbiter.

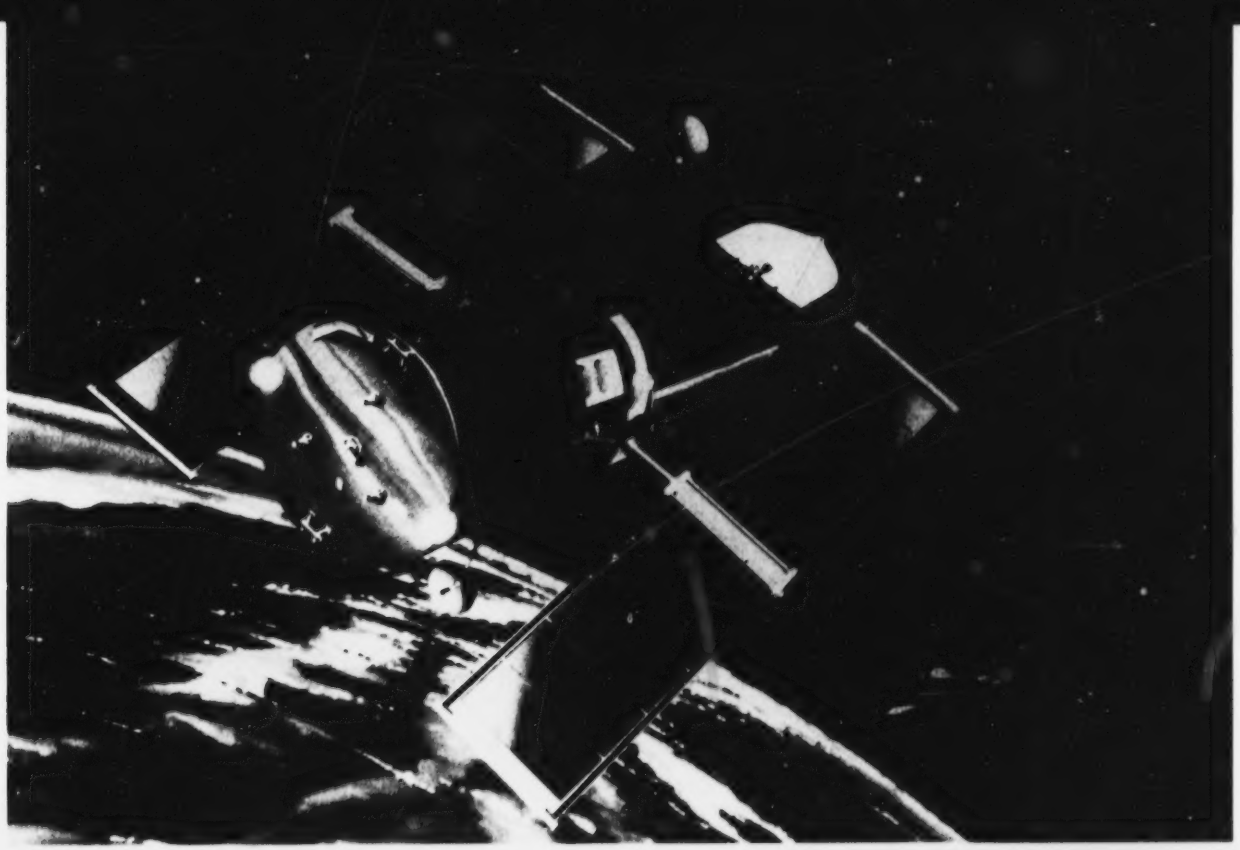


Infrared Observatory

Some celestial bodies glow only in the infrared portion of the spectrum, hence are largely invisible to ground observatories because most infrared radiation never reaches Earth; it is absorbed by water vapor in the atmosphere. Limited observations have been made from high altitude aircraft, balloons, sounding rockets and some spacecraft, but the infrared region remains one of the least explored areas of the spectrum. With the midsummer 1982 launch of the Infrared Astronomical Satellite (IRAS), scientists will have an instrument that will chart the universe in a new and important perspective.

Astronomical theory holds that stars being born do not "shine" in visible light, nor do stars in their death throes. In either instance, however, the stars' heat is emitted as infrared radiation. Thus, IRAS' array of 100 infrared detectors will be able to observe stars in all stages of their lifetimes—forming, aging and dying. That is perhaps the most exciting example, but it is only a part of IRAS' potential. The telescope will map as many as a million new infrared sources for future study and perhaps answer many fundamental questions about energy radiations from distant galaxies.

IRAS is a three-nation project in which the U.S. (NASA) is providing the telescope and launch services, The Netherlands the spacecraft and the United Kingdom the control center. Development of the 24-inch telescope is managed by Ames Research Center; Ball Aerospace Systems built the instrument. Jet Propulsion Laboratory is overall manager for the U.S. portion of the project.



Space Telescope

Scheduled for launch in 1985, the Space Telescope (above) will peer seven times farther into space than the largest ground-based telescopes. Operating above Earth's veil of atmosphere that blurs observations from the ground, the telescope will expand our view of galactic space 350 times and may enable scientists to see to the edge of the observable universe.

In 1981, the Space Telescope passed a major developmental milestone with completion of its 94-inch-diameter primary mirror, shown undergoing inspection (right) by technicians of Perkin-Elmer Corporation, which is producing the Optical Telescope Assembly. It took Perkin-Elmer more than two years to grind and polish the mirror to the exquisitely-accurate surface fineness essential to the telescope's performance. The company is now installing and aligning the various elements of the Optical Telescope Assembly preparatory to its integration with the Support Systems Module being built by Lockheed Missiles & Space Company. The European Space Agency is furnishing the solar panels and one of the system's five major instruments.

Forty-three feet long, the Space Telescope will be the largest astronomical system ever sent into orbit. Its development is being managed by Marshall Space Flight Center; Goddard Space Flight Center will manage the operational system. Images "seen" by the telescope will be instrument-analyzed, converted to electronic signals and beamed to Goddard, where the data will be computer-processed and the images reconstructed. Goddard will be tied electronically to the Space Science Telescope Institute on the campus of Johns Hopkins University in Baltimore, Maryland, where astronomers will view the images and get visual and printed readouts of the data. The Institute will be operated by a 16-university consortium known as the Association of Universities for Research in Astronomy.

Dynamics Explorers

The spacecraft pictured, shown undergoing preflight checkout, is Dynamics Explorer DE-1. DE-1 and its sister satellite DE-2 were launched last August into separate polar orbits. They are the latest in a series of Explorer satellites intended to provide an understanding of how energy from the Sun is transferred to a boundary region between Earth and space, and how this energy affects Earth's atmosphere, auroral displays, radio transmissions, perhaps weather and climate.

The boundary region the satellites are studying extends from the limits of the upper atmosphere to distances thousands of miles from Earth in the magnetosphere, the area controlled by Earth's magnetic field. Solar energy, in the form of light waves and matter, enters the magnetosphere, flows into the ionosphere—a region characterized by electrically charged particles—and eventually is deposited in the upper atmosphere. The Dynamics Explorer program, managed by Goddard Space Flight Center, is designed to provide new knowledge about the exchange of energy, electric currents, electric fields and charged particles in the magnetosphere, ionosphere and atmosphere.

Built by Ball Aerospace Systems, DE-1 and DE-2 are operating in the same orbital plane but in somewhat different paths. DE-1 is in a highly elliptical orbit with a peak altitude of about 14,000 miles; DE-2 is in a more nearly circular orbit with a top altitude of 800 miles. The different orbits allow the spacecraft to work as a team, one acquiring data in the magnetosphere while the other makes simultaneous measurements in the ionosphere and the upper atmosphere. DE-1 carries video cameras for an experiment of special interest: photographing the changing patterns of the "northern lights," which are evidences of the transfer of massive amounts of energy from the magnetosphere to the upper atmosphere.

Ozone Study

Launched last October, the Solar Mesosphere Explorer (SME) is an atmospheric research satellite whose findings are important to a matter of world concern: how natural influences or man-made contaminants impact Earth's protective layer of ozone. Created by complex chemical reactions in the atmosphere, the ozone layer effectively absorbs ultraviolet radiation from the Sun. Reduced ozone concentration, with consequent increase in the amount of ultraviolet radiation that reaches Earth, could adversely affect Earth's climate and agriculture, possibly human health.

The SME study focuses on the ozone-rich mesosphere, a region of Earth's atmosphere above the stratosphere and below the ionosphere extending from roughly 20 to 50 miles altitude. Equipped with five scientific instruments, SME is monitoring the reactions between sunlight, ozone and other chemicals in the atmosphere in an effort to determine how ozone is created and destroyed; the role each atmospheric constituent plays in ozone production and distribution; what changes in ozone levels result from changes in incoming solar radiation; and what factors other than sunlight cause changes in ozone abundance. Data from the mission will help develop models for ozone production and depletion on a global scale.

Jet Propulsion Laboratory (JPL) is manager of the SME project. Under contract to JPL, the University of Colorado's Laboratory for Atmospheric and Space Physics is responsible for the scientific instruments, mission operations and data evaluation. The spacecraft was built by Ball Aerospace Systems.

Technology Twice Used

Much of the technology generated by NASA's mainline programs is being adapted by private firms and public sector organizations for use in a broad range of new products and processes, providing economic and social benefits of significant magnitude

Spinoff developments highlighted in this section are based on information provided by secondary users of aerospace technology, individuals and manufacturers who acknowledge that aerospace technology contributed wholly or in part to development of the product or process described. Publication herein does not therefore constitute NASA endorsement of the product or process, nor confirmation of manufacturers' performance claims related to particular spinoff developments.

Spinoff from Space Fuel

Expanding civil use of liquid hydrogen, in applications ranging from fertilizer production to food processing, typifies the aerospace technology transfer process

On a Space Shuttle launch, the Orbiter's three main engines burn for about eight minutes and in that brief time consume some 380,000 gallons of fuel. The fuel is liquid hydrogen, which was also used in the Saturn V launch vehicle that sent Apollo astronauts to the moon. NASA selected hydrogen for these heavy-lift space vehicles because it is very light yet produces far more energy per pound than other rocket propellants. The company that supplied liquid hydrogen for Apollo and continues to produce it for the Space Shuttle program is Air Products and Chemicals, Inc., Allentown, Pennsylvania.

Last October, Air Products opened a new plant in Sarnia, Ontario, a landmark development in that it is the company's first liquid hydrogen facility dedicated solely to supplying the needs of non-government users. Sarnia produces 15 tons of liquid hydrogen daily and the plant is designed for double that output, an indication of mounting growth in commercial usage. Air Products' experience in government research, development and production of liquid hydrogen served as the springboard for a broad variety of practical, Earth-use applications.

Today, liquid hydrogen is widely used by petroleum refineries in sulfur-removal processes and in gasoline production; by chemical and pharmaceutical firms in manufacture of fertilizers and drugs; by food processors, who use it to make margarine and to keep oils fresh; by metals industries for heat-treating operations which harden and strengthen metal alloys; by electronics companies in growing crystals for electronic systems; by electric utilities for cooling large generators, motors and frequency changers. And new commercial applications are growing at the rate of about 10 percent a year.

"These applications would not exist today," says Edward Donley, Air Products' chairman, "had it not been for our government experience. Our work on government contracts gave us the technological know-how for large-scale production of liquid

Opened last October, Air Products' Sarnia, Ontario plant is the company's first facility for production of liquid hydrogen dedicated solely to the needs of non-government customers, an indication of growing civil use of the same substance that fuels Space Shuttle engines.

hydrogen, enabling cost reductions through economies of scale. That paved the way for expanded private sector use."

Air Products entered the picture in the mid-1950s when liquid hydrogen was little more than a laboratory experiment. NASA did not then exist, but the U.S. Air Force was studying hydrogen for both missile and space applications. Hydrogen's high-energy characteristics were known, but in gaseous form the element was not suitable for use in flight vehicles because of the very large volume of gas required. USAF research resulted in a process for liquefying hydrogen to reduce the volume, but another problem remained: liquid hydrogen was available only in laboratory-use amounts measured in hundreds of pounds per day, but extensive ground testing of rocket engines would demand production in tens of tons daily. Air Products, then an established producer of liquid oxygen, liquid nitrogen and other industrial gases and chemicals, was assigned the difficult job of pioneering tonnage production of liquid hydrogen.

Under USAF contract, the company built three plants from 1957 to 1959, the largest turning out 30 tons a day. About that time, a new and even larger requirement appeared when NASA began development of the Saturn V moonbooster, whose upper stages were powered by a high-thrust, hydrogen-burning rocket engine called the J-2. Years of exhaustive J-2 ground testing, coupled with the fuel needs for Apollo missions, created soaring demand for liquid hydrogen. In 1963, under contract with NASA, Air Products built a 32½ ton-a-day plant at Long Beach, California to supply West Coast rocket test facilities. In 1966, the company completed another 30 ton-a-day plant near New Orleans, Louisiana to serve NASA's Kennedy Space Center, Marshall Space Flight Center and the Mississippi Test Facility, where large rocket engines are test-fired. The advent of the Space Shuttle program further boosted NASA's liquid hydrogen needs; in 1977, Air Products added a 30 ton-a-day plant at the New Orleans site.

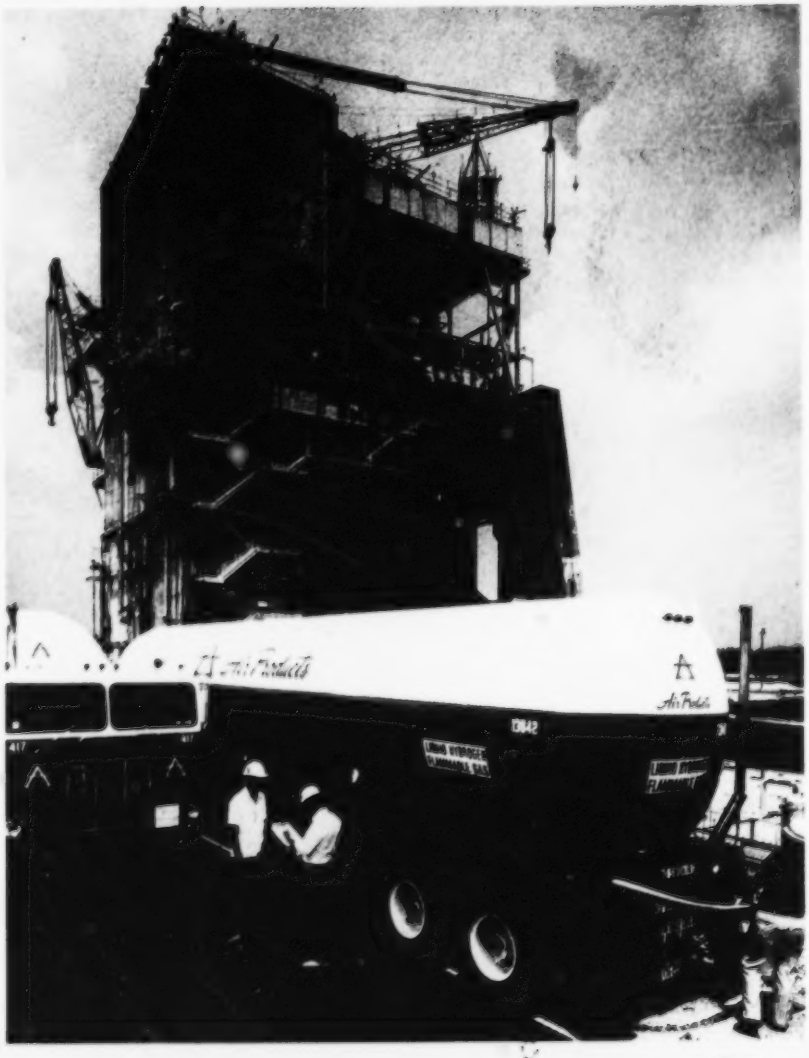
Over a quarter-century of government contract work, Air Products has acquired an enormous amount of technological know-how in all fields related to liquid hydrogen. The company pioneered safety measures for handling the potentially volatile substance and

Edward Donley, chairman of Air Products and Chemicals, Inc.: "Our work on government contracts gave us the technological know-how for large-scale production of liquid hydrogen . . . that paved the way for expanded private sector use."

disseminated its information to other producers. It developed design and construction techniques for high-quantity production, storage and transfer, including the world's only transfer system for loading barges from liquid hydrogen storage tanks. For overland distribution of the product, which must be maintained at the supercold temperature of minus 400 degrees Fahrenheit, the company built a fleet of specially-designed semitrailer tankers which boasts an impressive record in many million miles of road hauling. Most importantly, Air Products developed a number of processes for producing liquid hydrogen more efficiently, effecting cost reductions that inspired broader commercial use. Input from government research, Air Products' own technology development, and the large space program requirement combined to make the company the prime manufacturer of liquid hydrogen; its four plants turn out more than the total output of all other producers in the free world.

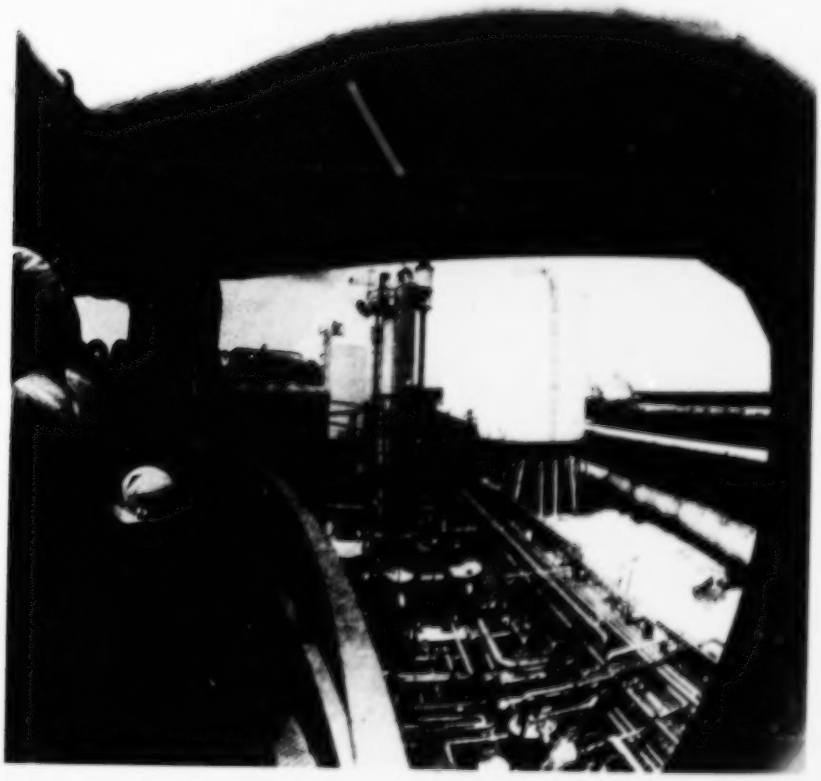
The Air Products story exemplifies the aerospace spinoff process. In this case, space needs created a large market for a new product; the NASA requirement, and the technology development necessary to its fulfillment, provided a base for company expansion into many non-government applications, with attendant benefit to the nation's Gross National Product and job creation. In other instances, the spinoff is government-developed technology rather than the growth and advancement spurred by a government requirement; once developed, technology can be reapplied in many avenues of everyday existence, often in ways surprisingly remote from the original application. Spinoff benefits valued in many millions of dollars are not unusual; in other spinoffs, the economic gain is only of moderate order, but the public benefits in other ways—from the introduction of new processes and products ranging from simple conveniences to significant developments in industrial and medical technology.

Through its Technology Utilization Program, NASA has actively promoted the secondary use of aerospace technology for two decades, during which thousands of aerospace-originated spinoffs have emerged. Collectively, they represent a substantial return on the aerospace investment.

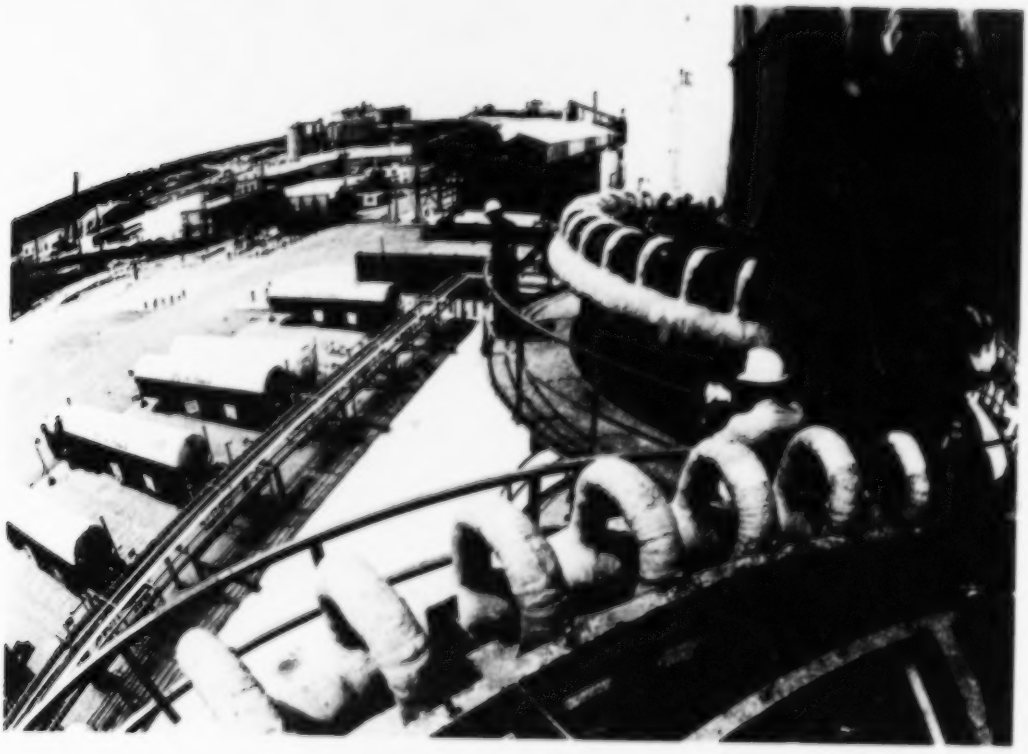


Above, a Space Shuttle engine is being tested at NASA's Mississippi Test Facility, Bay St. Louis, Mississippi. The Shuttle's main engines burn liquid hydrogen fuel supplied by Air Products and Chemicals, Inc. On a full-duration test, the engines may consume hundreds of tons of liquid hydrogen. High volume production for NASA and other government requirements gave Air Products a technology base for expansion into a variety of civil applications of liquid hydrogen.

Liquid hydrogen is a "cryogenic" fuel, meaning that it must be maintained at extremely low temperatures. To distribute the product from plants to users, Air Products built its own fleet of specially-designed cryogenic transport trailers, one of which is shown at left.

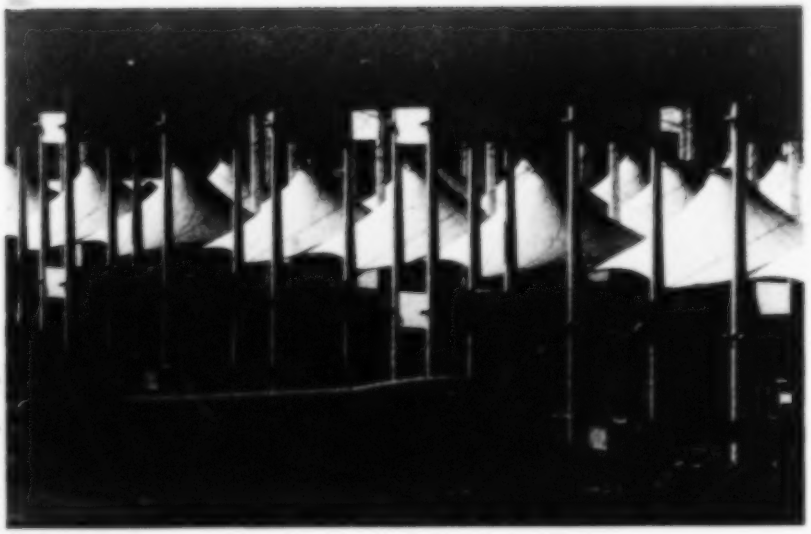


At its chemical complex near New Orleans, Louisiana, Air Products operates two plants which supply liquid hydrogen to NASA's Mississippi Test Facility and Kennedy Space Center. The plants have a combined output of 60 tons daily. The original plant was built in 1966 to meet the fuel needs of the Apollo program; the second facility was added in 1977 when Space Shuttle engine testing began. In addition to the New Orleans complex, Air Products operates liquid hydrogen plants at Long Beach, California and Sarnia, Ontario.



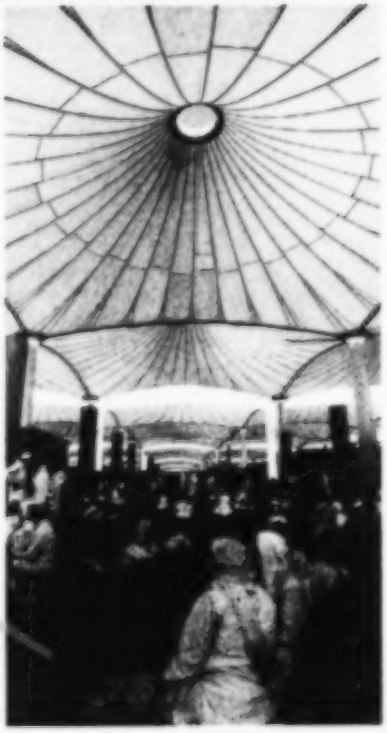
A mammoth Saudi Arabian air terminal's roof, made of aerospace-originated fabric, highlights spinoffs in transportation

Hostel for the Hajjis



Owens-Corning Fiberglas

Designed to look like a tent city, Saudi Arabia's Haj Terminal in Jeddah is a rest stop for Mecca-bound pilgrims, or hajjis. *Made of spinoff material, it is the world's largest fabric structure.*



Owens-Corning Fiberglas

Although temperatures outside sometimes reach 130 degrees, it is a comfortable 80 under the "big top;" the coated fabric roof reflects 75 percent of the Sun's radiation and a unique open-sided, open-top tent design promotes cooling air circulation.

In Islamic teaching, the holiest of all places is Mecca, the birthplace of the Prophet Muhammad in Saudi Arabia's Hejaz region bordering the Red Sea. Some 800 million Muslims turn toward Mecca five times daily to pray to Allah. Each of them hopes some day to make the ultimate act of devotion—the *haj*, the pilgrimage to Mecca.

This year, more than a million *hajjis* from all over the world will realize that ambition. Most will make the journey by air, arriving at the new King Abdulaziz International Airport (KAIA) in the gateway city of Jeddah, a Red Sea port 45 miles from Mecca. There they will sojourn briefly at KAIA's Haj Terminal, a colossal facility built by the host nation to ease entry formalities for the massive influx of *hajjis* and to provide them a place of rest before they embark on the final lap of the pilgrimage.

Other air travelers are processed elsewhere at KAIA, but the Haj Terminal is reserved for Muslim pilgrims. A broad expanse of fabric cones, it is designed to suggest the tent cities in which *hajjis* have sheltered themselves during centuries of pilgrimages. The terminal consists of two identical structures separated by a landscaped mall. Each structure has a multi-tented fabric roof spanning more than 50 acres. Together, the structures contain 210 individual tent units and cover an area roughly equivalent to 80 football fields. That makes the Haj Terminal the world's largest fabric structure.

The roof covering is Fiberglas* fabric coated with Teflon* fluorocarbon resin. The fabric is supplied by Owens-Corning Fiberglas Corporation, Toledo, Ohio. Teflon is a product of Du Pont Company, Wilmington, Delaware.

* Fiberglas and Beta are registered trademarks of Owens-Corning Fiberglas Corporation.

* Teflon is a registered trademark of Du Pont Company.

Owens-Corning Fiberglas

After entry formalities and a day's rest, the hajjis board buses for the final leg of the journey, to the holy cities of Mecca and Medina.

The material is an aerospace spinoff whose origin dates to 1967, when NASA was looking for a new fabric for astronaut space suits. Owens-Corning had been experimenting with an ultrafine pure glass fiber yarn called Beta® that seemed to meet all requirements. The yarn was woven into a fabric, coated with Teflon and tailored for astronaut wear. The material thus produced provided the basis for heavier, construction-use adaptations which have found wide acceptance as permanent architectural fabrics for structures all over the world.

Use of the fabric was an answer to a design question pondered by the New York/Chicago firm of Skidmore, Owings & Merrill (SOM), architects and engineers for the Haj Terminal project, and the Saudi Ministry of Defense and Aviation. There was a problem in that the great annual influx of *hajjis* occurs in a short time frame, the 70-day pilgrimage season, thus greatly increasing the daily rate of entries. It was necessary to plan for processing as many as 5,000 persons an hour and for sheltering up to 100,000 at a time—in an area where the temperature may reach 130 degrees Fahrenheit. It would have been next to impossible to build, maintain and air-condition a single conventional, fully-enclosed structure to meet both processing and shelter requirements.

SOM, therefore, decided to provide two kinds of covered space. For customs, immigration, baggage handling and other processing operations, where people would be working 24 hours a day, the firm designed a pair of two-story enclosed air-conditioned buildings. For the shelter area, SOM decided upon the open-sided, tented-roof structure. In lieu of air conditioning, the white Fiberglas fabric, coated with Teflon on both sides, reflects 75 percent of the solar radiation reaching the roof, thus helping to curb under-roof heat. Additionally, the conical tents are open at top and sides, creating a natural venturi effect that promotes a cooling upward flow of air. The fabric's reflectivity, coupled with the air circulation stimulated by the constant desert wind, keeps terminal temperatures in the 80 degree Fahrenheit range even when outside temperatures reach 130.

Each of the 210 tents measures 150 by 150 feet at the bottom and stands 66 feet above the terminal floor. The tents are suspended by steel cables attached to 150-foot steel pylons; the cables support, strengthen and shape the fabric. In addition to its reflectivity, the fabric offers a number of other advantages. It is translucent and permits shadowless natural light to filter to the under-roof area, creating a softly shaded environment that eliminates the need for artificial daytime lighting. It resists the corroding effect of salt air generated by the Red Sea. It also plays a part—along with the conical tent design and the roof height—in diminishing the acoustical problems created by many thousands of pilgrims in the terminal. Very strong and durable, the Teflon-coated Fiberglas fabric gives the roof a life expectancy of more than 30 years.

Fabric structures as temporary shelters date back to 1948, but their use as permanent alternatives to conventional buildings has grown markedly in the past decade, spurred by the availability of advanced materials. Some examples of other structures that incorporate Fiberglas fabric are pictured on the following pages.

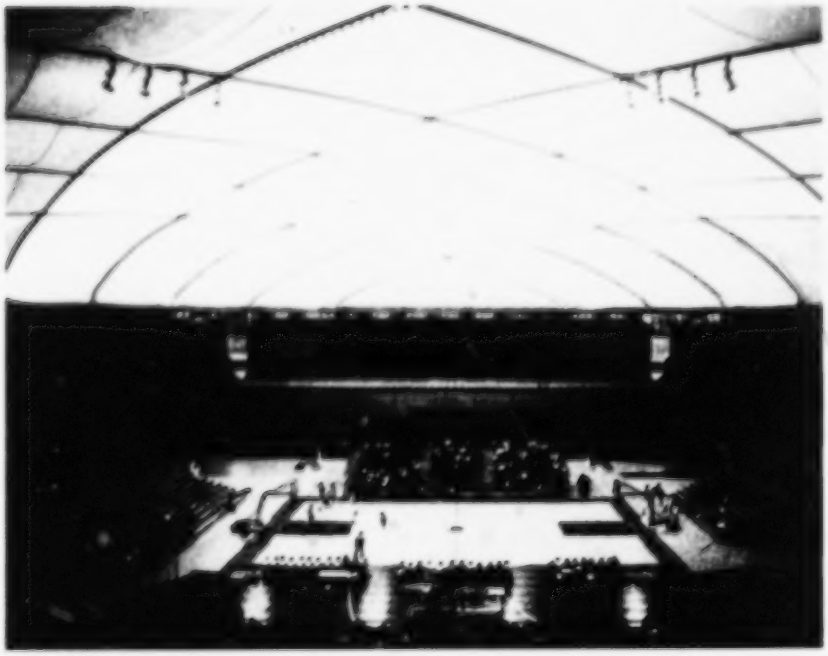
Owens-Corning Fiberglas

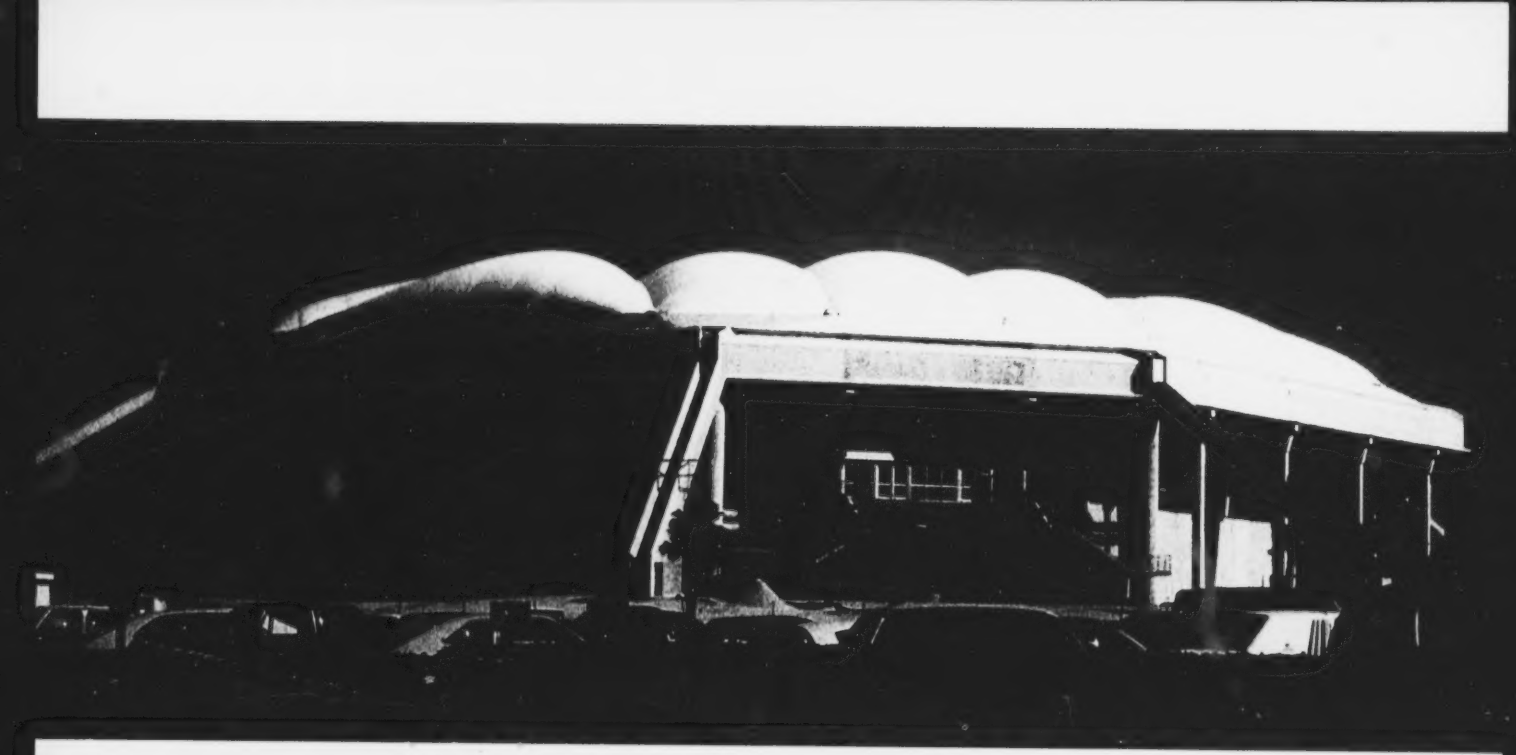
The many colorful souks, selling modern and traditional wares, need no artificial daytime lighting; the translucent fabric admits natural light. In addition to the souks, the huge terminal has facilities for processing passengers, many restaurants, lavatories, travel service counters, banks and rest areas.

Other Fabric Structures

Architects, engineers and building owners are turning increasingly to fabric structures because of their aesthetic appeal, relatively low initial cost, low maintenance outlays, energy efficiency and good space utilization. On these pages are examples of U.S. structures whose roof coverings are made of Teflon-coated Fiberglas fabric. Some, like the Haj Terminal, are tension structures supported by a network of cables and pylons; others are supported by air pressure within an enclosed, inflated fabric envelope.

Above is Bullock's Department Store, San Jose, California, which has an 18,000 square foot light-transmitting fabric roof covering the center third of





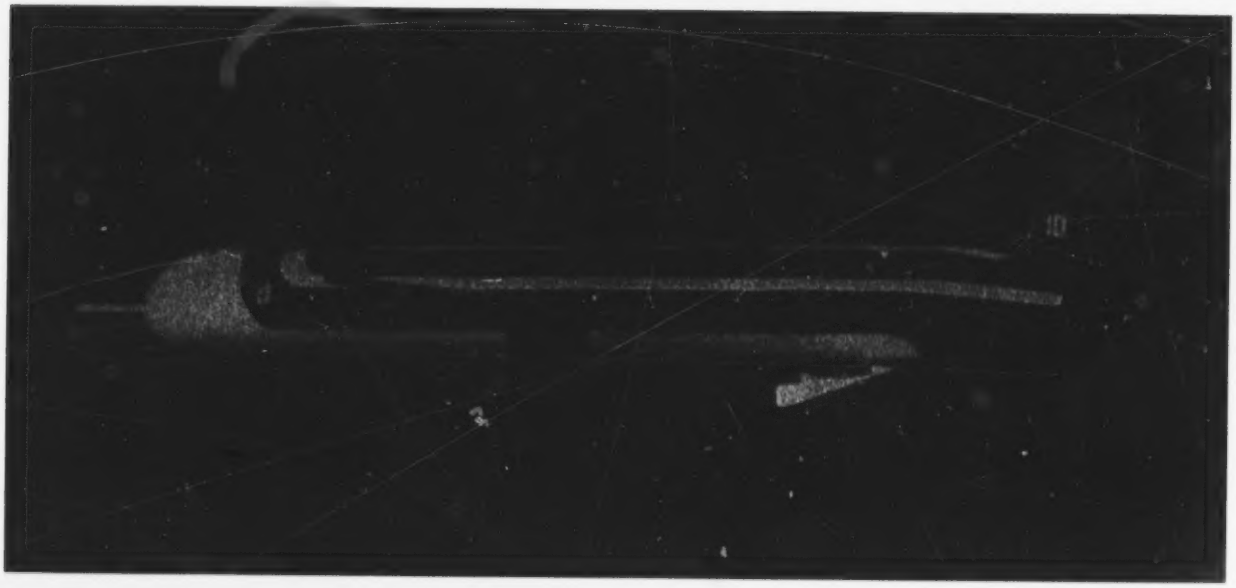
the store's upper level. At center on the opposite page is Sea World's Florida Festival in Orlando, a showcase for Florida's natural and man-made products. Below it is the University of South Dakota's DakotaDome at Vermillion, a physical education and student recreation center. Above is a similar facility—called the Sun Dome—at the University of South Florida, Tampa. Perhaps the best known of all fabric structures, by virtue of its television exposure, is the Pontiac, Michigan, home of the National Football League's Detroit Lions, the Silverdome (below).

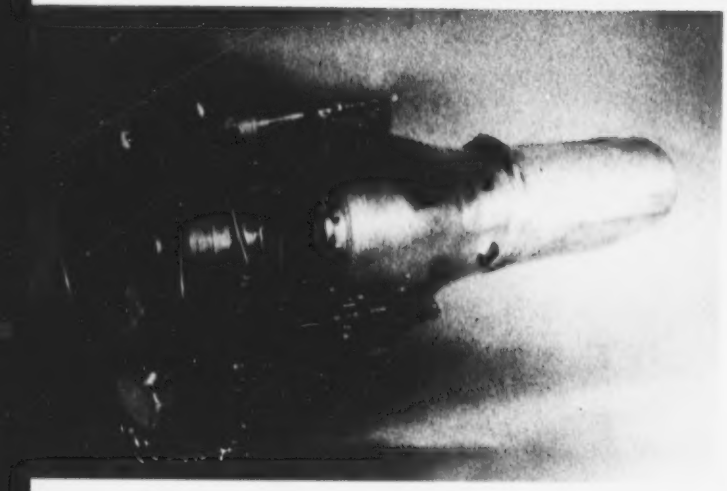
Airline Wheelchair

Some 700,000 people in the United States rely on wheelchairs for mobility. Few of them travel by air because of difficulties encountered at airports, in boarding airliners, and particularly in mobility within the airplane. For several years, the Rehabilitation International Commission and its American affiliate—Rehabilitation International U.S.A. (RIUSA)—have been studying the matter and seeking to remove air travel barriers for the mobility impaired. A multi-organizational cooperative program has provided a major first step: a wheelchair capable of passage through narrow airliner aisles to move passengers to their seats and to give them access to lavatories. Participants include RIUSA, the designers and producers of several prototype chairs, a number of domestic and foreign airlines, and Aerospace Industries Association, representing the three major U.S. jetliner manufacturers (Boeing, Lockheed and McDonnell Douglas). The prototype chairs have been undergoing evaluation aboard commercial airlines since mid-year 1981. Each participating airline will select its own design from among the prototypes. The wheelchairs are expected to enter airline service next year.

Pictured at right is one of the prototypes, which incorporates NASA technology. The chair was designed by the University of Virginia (UVa) Rehabilitation Engineering Center with support from the National Institute of Handicapped Research and from Langley Research Center, which applied aerospace technologies in structural analysis and materials enginnering. NASA's Research Triangle Institute Biomedical Applications Team, Research Triangle Park, North Carolina coordinated the UVa/Langley teamwork. The UVa/Langley chair was the first of the competing prototypes to be ordered by an airline; United Air Lines contracted for 15 units, to be built by Accutron Tool and Instrument Company, Hampton, Virginia.

Since weight is a factor in any item of equipment aboard a commercial airliner, the wheelchair had to be much lighter than conventional wheelchairs; it also had to be stable, durable, comfortable and easy to handle. The UVa/Langley prototype is made of Langley-furnished composite materials and weighs only 17 pounds, about one-third the weight of a standard wheelchair. It fits airliner aisles (below) and can support a 200-pound person. Called the "Stowaway," it can be folded and stowed when not in use (left).





Cruise Missile Engines

Beginning this year, the Department of Defense plans to deploy two types of cruise missiles. One, shown above, is the Navy-sponsored Tomahawk, developed by General Dynamics Corporation; the Tomahawk can be launched from submarines and surface ships or from land bases. The other is the Air Force AGM-86B Air Launched Cruise Missile (ALCM), developed and manufactured by The Boeing Company. Cruise missiles are necessarily small, so they need a small but highly efficient engine to propel them over long distances at relatively high speeds. The Tomahawk and the ALCM are powered by the same type of engine, a Williams F107 fanjet (left) that produces about 600 pounds thrust, is one foot in diameter and weighs only 141 pounds. The engine is manufactured by Williams International, Walled Lake, Michigan, one of the world's largest producers of small gas turbines for aircraft, automotive, industrial and marine applications.

In developing the F107 engine, the Williams International design engineering staff used a computer program from the inventory of NASA's Computer Software Management and Information Center (COSMIC)®, which routinely supplies such programs as a service to industry (see page 66). The COSMIC program was used in calculating airflows in the engine's internal ducting; flow analysis is a design step toward assuring optimum flow rate, which results in a more efficient engine with increased thrust and reduced fuel consumption. The company also uses the COSMIC software on an ongoing basis as new projects are initiated.

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Helicopter Design Analysis

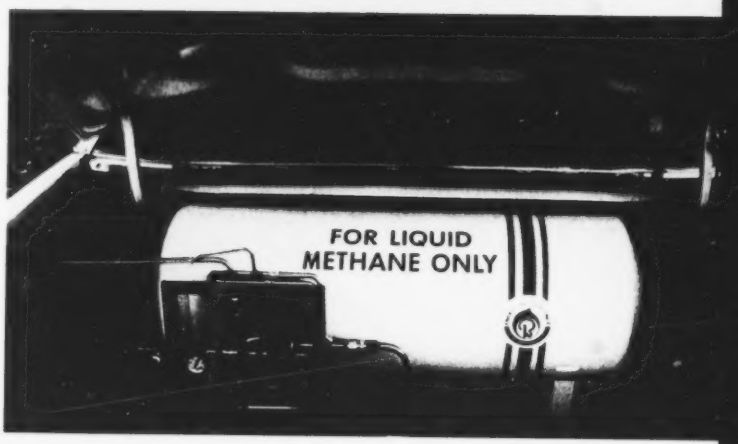
The helicopters pictured are the Model 214ST, an 18-place craft developed primarily for the offshore petroleum and construction industries, and the Model 412 executive transport (bottom). They are two of a line of civil and military helicopters produced by Bell Helicopter Textron, Fort Worth, Texas. In designing the helicopters shown and other craft, Bell makes use of a NASA/COSMIC computer program known as VASP. The program is employed in analysis of helicopter hardware and as a guide for postulating new designs for autopilot equipment. The company reports that use of VASP enables performance of more accurate analyses to insure product safety; the COSMIC program also aids improved production efficiency.

Methane-powered Vehicles

In the continuing quest for energy alternatives to expensive oil, liquid methane is beginning to make inroads as a power source for automotive vehicles. The principal component of natural gas, methane costs less than half as much as gasoline, according to a study by the American Gas Association, and its emissions are considerably cleaner than those from gasoline or diesel engines. In a development based on aerospace technology, Beech Aircraft Corporation's Boulder (Colorado) Division has designed and is now producing a system for converting cars and trucks to liquid methane operation.

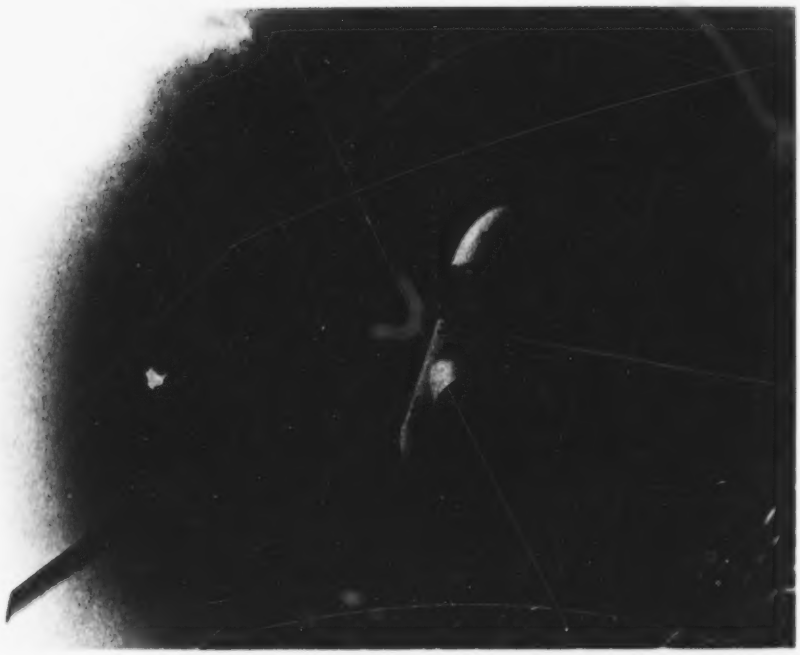
The accompanying photos show the company's methane-powered demonstration car and, in the trunk, an 18-gallon fuel tank. Liquid methane (LM) is a "cryogenic" fuel which must be stored at a temperature of 260 degrees below zero Fahrenheit. In designing the LM tank, Boulder Division drew upon space technology acquired in producing cryogenic storage systems for NASA's Apollo and Skylab spacecraft and for the Space Shuttle. In addition to the tank, the LM system includes simple "under the hood" carburetor conversion equipment (top right). An optional twin-fuel system enables the vehicle operator to use either LM or gasoline fuel.

Last year, Beech received its first substantial contract for the system from Northwest Natural Gas Company, Portland, Oregon. Boulder Division has started deliveries on an order for 25 vehicle conversions and is furnishing a liquid methane refueling station. Beech is also providing instruction for Northwest Natural Gas personnel. The latter company has its own large natural gas supply and a facility for converting methane to liquefied state.

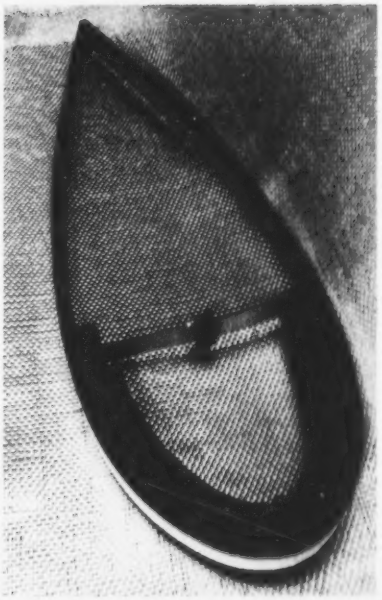


A Two-Way Spinoff

An unusual technology transfer, involving sailboats and commercial wind energy systems, highlights spinoffs for home, consumer and recreational use



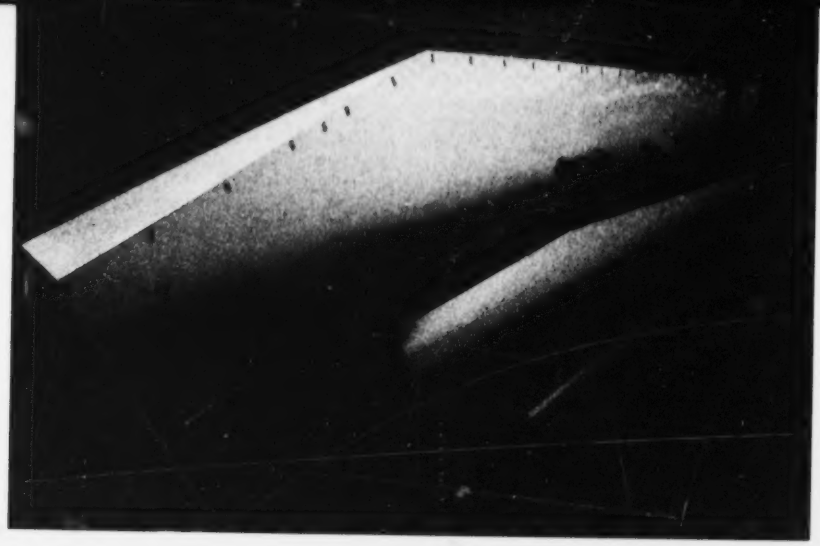
This NASA-developed wind turbine generator in Hawaii provides enough electricity for 100 homes. Its wood composite blades were made by Gougeon Brothers Inc., a Michigan sailboat builder which has also become a leading firm in commercial wind turbine manufacture.



This cross-section view of a 60-foot wind turbine blade illustrates the Gougeon technique of laminating multiple layers of wood, bonded by a plastic substance, to produce a light, strong and very stable structure.

Gougeon Brothers Inc, Bay City, Michigan is a small business producer of high-performance sailboats, iceboats and wind turbine rotor blades. That may sound like an oddly mixed product line but, in this instance at least, there is a direct connection between boatbuilding and bladebuilding; the Gougeons—Meade, Jan and Joe—got into the blade fabrication business as a result of their boat construction expertise. It's an unusual spinoff story, because the technology initially transferred did not flow from NASA to the Gougeons—it was the other way around. The Gougeons successfully applied their boatbuilding know-how to a NASA problem in wind turbine development and eventually the spinoff benefits came full-cycle: as a result of their NASA involvement Gougeon Brothers not only acquired a whole new product line but also expanded its engineering competence and improved its boatbuilding techniques.

It started several years ago when NASA and the Department of Energy, looking for energy alternatives to fossil fuels, began experimenting with large wind turbine machines. A wind turbine is simple in principle; a modern counterpart of the age-old windmill, it harnesses the power of the wind to spin a bladed rotor, which in turn drives an electricity-generating turbine. However, the wind turbine loses some of its simplicity as it gets bigger. To generate electricity on a large scale requires supersize rotor blades, and with increasing size comes increasing stress and strain on the spinning blades. That was the problem Lewis Research Center faced in developing a first generation wind turbine generator known as MOD-OA, a 200,000-watt system with a rotor diameter of 125 feet, including two 60-foot blades affixed to the turbine-driving rotor



The large blade in the picture is a 60-footer developed for NASA; the smaller blades are Gougeon products manufactured for commercial wind turbines that provide electricity for homes, farms, apartment complexes and small utilities.

hub. Produced by a leading aerospace firm, the metal blades kept failing under stress. Lewis researchers were exploring every avenue in search of an answer.

The Gougeons, it turned out, had an answer. At Bay City, on Lake Huron's Saginaw Bay, they were turning out high quality boats based on techniques they had developed for fabricating wood composite structures. Their composites were multiple laminated layers of various woods bonded together by epoxy resin adhesive. They used a high percentage of adhesive to get a composite with a ratio of about 75 percent wood to 25 percent plastic, which resulted in a structure lighter yet stronger and far more stable than solid wood.

At a boatbuilding seminar in Cleveland, Ohio, Gougeon Brothers chairman Meade Gougeon described his company's special techniques to an audience that included a very interested Lewis Research Center engineer. This, thought the man from Lewis, could be the answer to the MOD-OA wind turbine's problems—strong and highly stable wooden blades that might stand up better under stress than metal.

To brief a story that took a couple of years to unfold, the Gougeons were interested in trying their hand at building a wind turbine blade. NASA officials visited the Bay city facility to check out their competence, a contract was awarded to study the feasibility of wood blades in wind turbines, and Gougeon Brothers went on to build several sets of blades for the MOD-OA system; all worked successfully. The basic blade was made of multiple laminates, as many as 76 layers in some places, mostly of fir with some spruce and birch; it turned out to be not only better than its metal predecessor, but cheaper. One set of blades is still going strong, after several thousand hours of operation, in a wind turbine in Oahu, Hawaii; NASA fatigue tests indicate the blades could last 30 years.

The NASA assignment involved extensive research by Gougeon Brothers and led to the company's development of new manufacturing processes for producing high-quality wood composite structures at low cost. One result is that the company has become a leading blade producer in the small but growing industry which manufactures wind energy systems. For Enertech, a Norwich, Vermont manufacturer of small wind machines, Gougeon Brothers produces a 10-foot and a 22½-foot blade used in a 4,000-watt generator designed for home use. Gougeon supplies blades of 22½ and 26½ feet to Energy Sciences, Inc., Boulder, Colorado for wind turbines generating power for farms, apartment complexes and small utilities. Gougeon Brothers has also been selected as blade subcontractor in a General Electric Company project involving the largest wind turbine yet designed—a 400-foot diameter system capable of feeding utility companies 6-7 million watts of electricity per hour.

In the course of studying rotor blade aerodynamics, Gougeon Brothers also acquired new know-how applicable to boatbuilding, for example, the company's innovative "aerodynamic mast" for sailboats. Large boat masts are generally supported by rigging and held in a fixed position. The Gougeons have developed a strong, lightweight wood composite mast which needs no supporting rigging and is free to rotate with the wind. The mast becomes, in effect, the leading edge of a mast/sail airfoil which operates like a highly efficient airplane wing. This provides a sailboat a new degree of propulsive efficiency and it could, says Meade Gougeon, make commercial sailing feasible; used as an auxiliary power source, the rotating mast sail could cut a ship's fuel cost by as much as 40 percent.

Company chairman Meade Gougeon (in red) displays the innovative "aerodynamic mast", an efficiency improvement for sailboats inspired by Gougeon Brothers' work on NASA wind turbines.

Cool Sportswear

Last year's New York Marathon (below) offered an appropriate setting for introducing a new line of athletic wear and Techni-Clothes Inc. of New York City was on hand to demonstrate its space-spinoff apparel. Techni-Clothes is headed by Dr. Lawrence H. Kuznetz, who is also a bioengineer and physiologist at Johnson Space Center (JSC), working in the Space Shuttle program. With the help of some JSC colleagues, Kuznetz has developed a number of commercial products based on his space expertise, in particular his experience in designing circulating liquid cooling systems for astronauts' space suits.

Techni-Clothes' initial line is a series of items for cooling athletes, allowing them to perform more

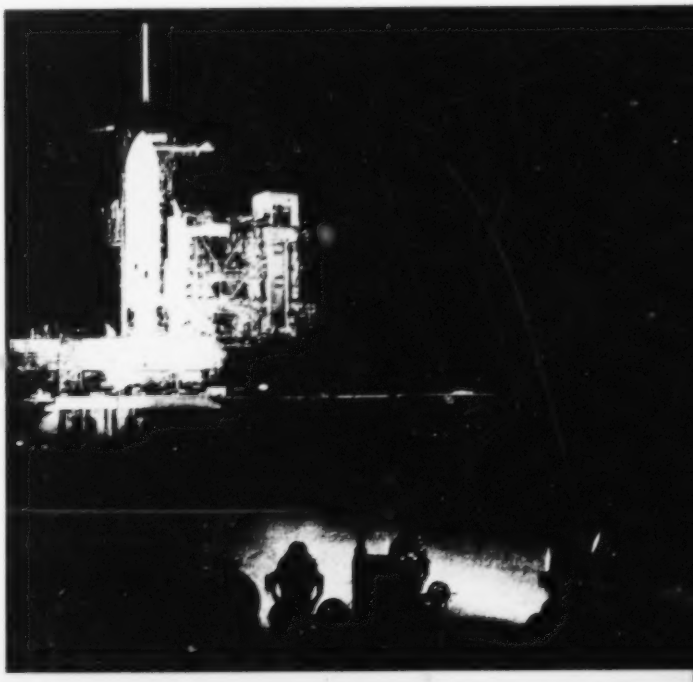
strenuous activity without becoming overheated. Like the space suit, the apparel is designed to remove heat by the circulating liquid method, which would have been too cumbersome for sports use. Instead, Techni-Clothes gear incorporates packets containing a heat-absorbing gel, a more efficient version of the "blue-ice" sold for use in picnic coolers. The gel packet slips into an insulated pocket of the athletic garment (left) and is positioned near parts of the body where heat transfer is most efficient—for example, the forehead, neck or wrist. A gel packet is good for about an hour; it can be replaced from a supply of spares in an insulated container worn on the belt.

At top right, a pair of New York marathoners run through warmup exercises, each wearing a cooling headband; in the bottom right photo, marathoners display other Techni-Clothes headgear. The company s

line also includes wrist bands and running shorts with gel-pack pockets. The products are targeted primarily for the estimated 25 million runners and joggers in the U.S., but they can be used by any athlete whose performance may be affected by hot weather.

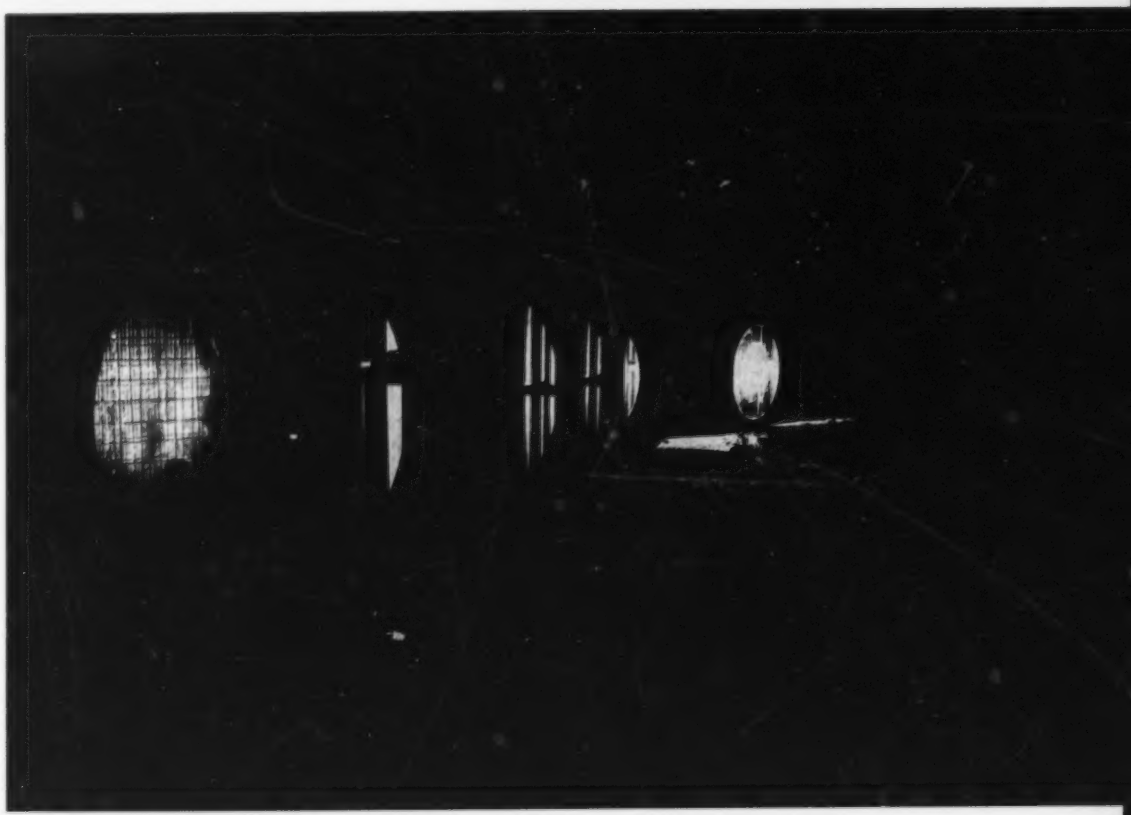
The photo at left illustrates still another Kuznetz product, also a space spinoff but based on somewhat different technology. In this application, Kuznetz employed materials technology and systems engineering techniques to design a bra for female runners and joggers. Called the Support-Her Bra, it is manufactured by Protogs Inc., Hicksville, New York. The halter-like garment is not just a modesty aid to curb embarassing "mammary bounce;" made of a knit interlining and a nylon mesh outer shell, it is a carefully engineered restraint and support device intended to prevent shoulder and back strains, abrasions and other problems encountered by women runners, particularly those with large breasts. The items pictured are the first to become commercially available, but Kuznetz and his associates have designed several other space spinoff products, including special purpose clothing, survival gear and medical rehabilitation devices.

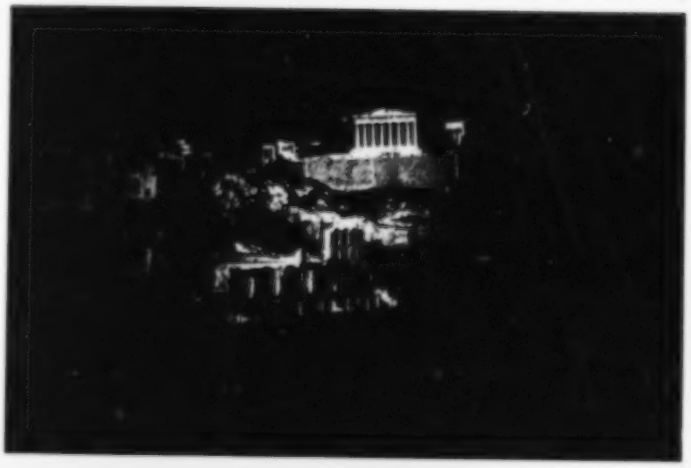
High-intensity Lighting



At right is a nighttime view of the Space Shuttle at Kennedy Space Center's (KSC) Launch Complex 39, illuminated by the world's most intense floodlighting system. The system consists of 50 searchlights, each containing a 20,000-watt xenon lamp, one of which is shown in closeup below; the lamp was developed by Duro-Test Corporation, North Bergen, New Jersey. Nighttime illumination is an important part of round-the-clock pre-launch preparations because NASA uses TV and film cameras to monitor each step of the preliminaries and at times to identify the cause of malfunction during countdown. Generating a one billion candlepower beam visible 50 miles away, the lamps provide daylight quality light that eliminates color distortion in film and TV coverage. The lighting system was first used at KSC for the 1968 launch of Apollo 8 and has been employed for all subsequent launches.

Modified versions of this system have found utility in a wide range of spinoff applications. For example, a battery of spotlights with colored filters (bottom) lights up Niagara Falls (right). This system employs a 4,500-watt lamp manufactured by the same techniques perfected in fabrication of the NASA lamp. The 4,500-watt lamps are used extensively in projection systems for outdoor theatres; the increased intensity allows larger screens.

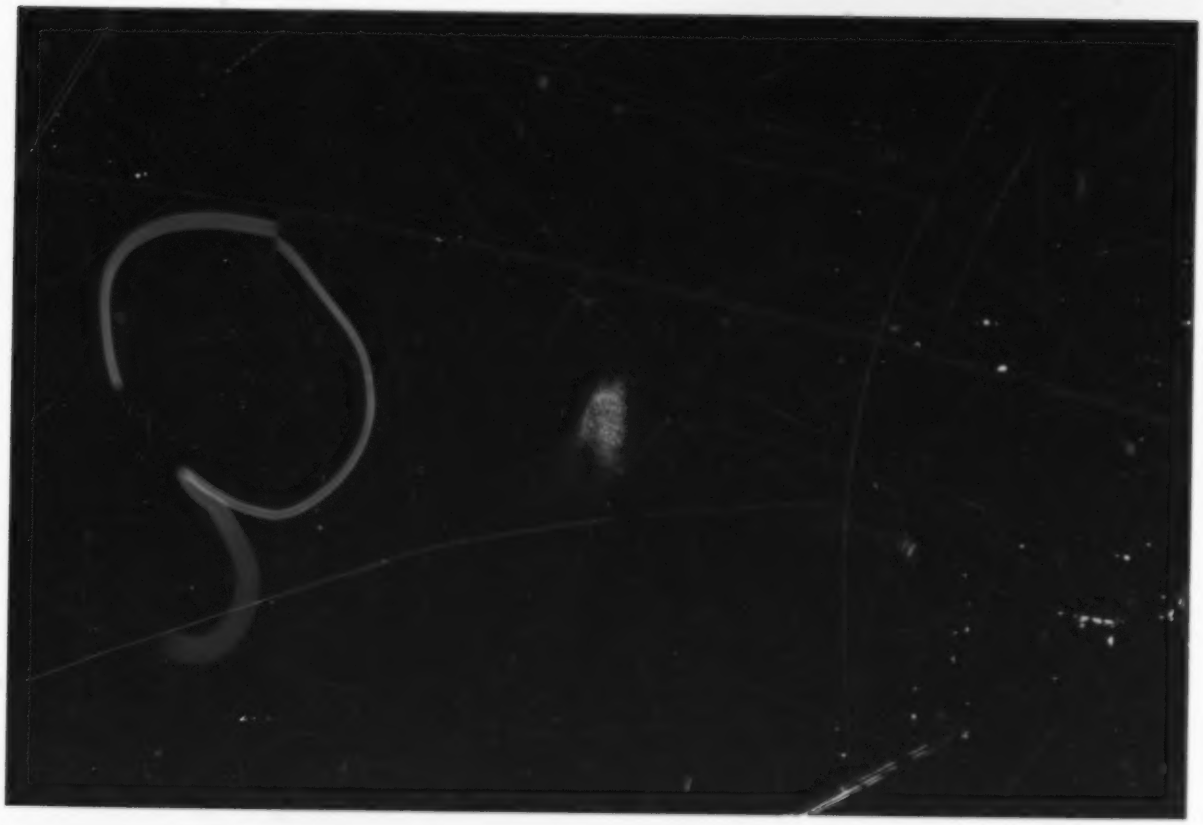




hence greater theatre capacity.

At right, a Smithsonian Institution projectionist at the National Air and Space Museum, Washington, D.C. sets up a 70-millimeter Imax projector for a presentation of the show "Living Planet" on a 48 by 75 foot screen in the museum's auditorium (center). Duro-Test teamed with the projector designer—Imax Entertainment Limited, Canada—to build a 12,000-watt xenon lamp for the system, again based on Duro-Test's work for NASA. The projectors are used at indoor theatres with supersized screens; there are 15 installations in North, South, Central America and Japan. The 20,000-watt version is used in solar simulators operated by several NASA centers, aerospace manufacturers and other research organizations in the U.S. and abroad.

Duro-Test xenon lamps operate on the principle of passing a a high electric current between two tungsten electrodes centered in a quartz bulb filled with xenon gas, which radiates light closely comparable to natural sunlight. The electric current heats the gas to a temperature of about 6,000 degrees Centigrade, thus creating the high intensity radiation. Duro-Test initially developed the 20,000-watt lamp for the Army and refined it under NASA contract to meet demanding specifications required by KSC for its use in launch lighting and in solar simulators. The company is working on advanced lamp designs to meet a demand for solar panel testing and for improving the product line in general.



Advanced Welding Tool

Whitewater canoeing is a growing sport and one that sometimes poses a problem for its devotees: canoe gashes are frequent but very difficult to repair. The reason is that many canoes are made of plastics and there are few means of repairing these materials. Canoeists who live in the Potomac River area of Virginia are lucky—they have Dave Brown, whose Great Falls Canoe and Kayak Repair, Vienna, Virginia is one of only two canoe repair facilities in the eastern U.S. Brown has developed special repair techniques based on operation of the Inductron Toroid Welder he is using at right. Canoe repair is only one of a great many applications for this versatile spinoff device, which is produced under NASA license by Inductron Corporation, Grafton, Virginia.

The welder was originally developed by Langley Research Center as a tool that could be used in any atmosphere, including the airless environment of space. It was developed specifically for joining parts made of plastic or composite materials, which are difficult to join by conventional methods. Adhesive bonding is not reliable in a vacuum, riveting techniques often deform the plastic, and mechanical fasteners require hole preparation and special hardware. So the Langley developers decided on induction, or magnetic heating, which causes little or no deformation and can be used with almost any type of thermoplastic material. An induction coil transfers magnetic flux through the plastic to a metal screen, which is sandwiched between the sheets of plastic to be joined. When the welder is energized, the alternating current produces inductive heating on the screen, causing the adjacent plastic surfaces to melt and flow into the mesh. This creates a bond of the total surface area, where conventional hot gas welding produces only a peripheral bond.

The commercial Inductron model is a self-contained, portable welding gun with a switch on the handle to regulate the temperature of the plastic-melting screen. Capable of joining dissimilar materials, which may be thermoplastic or non-thermoplastic, the welder has a broad range of applications in the automobile, appliance, aerospace and construction industries.

Water Filter

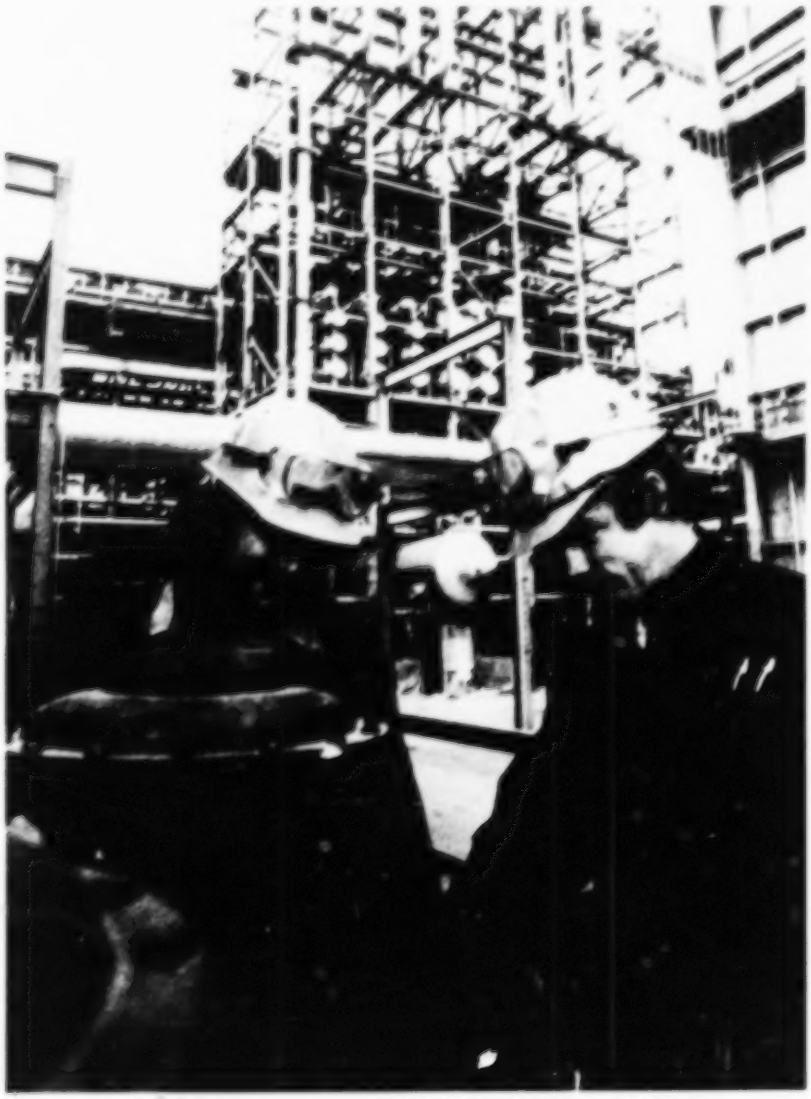
When Ray Ward moved from Utah to Arizona, he didn't like the taste of the water, so he decided to develop his own water filter. Today, only five years later, he is president and board chairman of Bon Del Manufacturing Company, Mesa, Arizona, whose filters are sold worldwide by some 20,000 distributors.

During extensive research on various types of filtering systems, Ward learned of a NASA unit designed to purify water supplied aboard the Space Shuttle Orbiter. Developed by Chemtric, Inc., Rosemont, Illinois, A compact, lightweight electrolytic water sterilizer, it generates silver ions—in concentrations of 50 to 100 parts per billion—in the water flow system. The silver ions serve as an effective bactericide deodorizer. Ward received technical information from NASA on the sterilizer and used it as the basis for his own development, which is known as the Bon Del Bacteriostatic Water Filter. Ward had originally not planned to manufacture the unit, simply to build a filter for personal home use. But friends and neighbors who learned of the unit wanted one; their rapid acceptance launched a booming business.

About the size of a thermos bottle, the Bon Del filter attaches to a faucet. Tap water passes through a filtering element of silver which has been chemically plated onto activated carbon. The silver inhibits bacterial growth while the activated carbon removes objectionable tastes and odors caused by addition of chlorine and other chemicals to the municipal water supply. Bon Del produces the filter in three models: a kitchen unit (upper left), the company's best seller; a "Tourister" unit for portable use while traveling (upper right); and a refrigerator unit that attaches to the ice cube water line. A filter will treat 5,000 to 10,000 gallons of water. Bon Del is introducing new designs in 1982.

Computer Technology for Industry

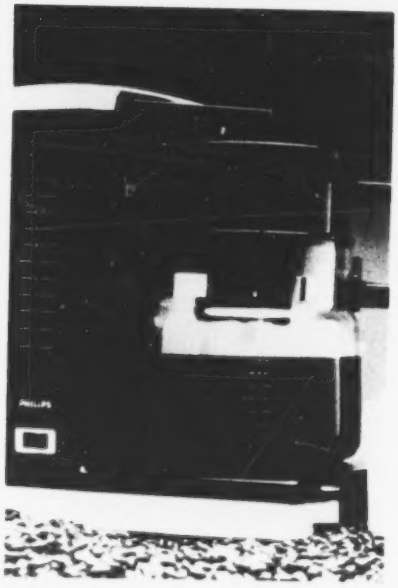
A special NASA service is contributing to national productivity by providing industry with reusable, low cost government-developed computer programs



Information processing by computer is experiencing explosive growth in the United States and multifold expansion is predicted for the 1980s. Spurred by the need to improve business efficiency in today's uncertain economic environment, thousands of companies are joining the ranks of computer users annually, while longtime users are regularly finding new ways to improve their operations by computerization. In the interests of national productivity, NASA is helping American businesses to reduce automation costs through use of previously developed computer programs that have secondary utility.

Computer programs, called "software," are sets of instructions that tell a computer how to draw upon its stored input to produce desired information or effect. Development of an entirely new program is time-consuming and expensive; software costs sometimes amount to 30-40 percent of the total cost of computerizing a business or

Shown above is the Shell Oil Company plant at Norco, Louisiana, one of several at which the company produces chemical compounds used in the manufacture of plastic products. Examples of the many products include children's toys, vacuum cleaners, coffee makers and fruit juice bottles. Shell is among the many companies which have benefited from use of NASA COSMIC computer programs in industrial operations.



a process. Frequently, however, a program developed for one purpose can readily be adapted to a totally different application. Thus, industrial software users can save time and money by taking advantage of a national resource available to them: the large "bank" of computer programs developed in the course of work sponsored by NASA, the Department of Defense and other technology-generating agencies of the government.

NASA's mechanism for making such programs available to the private sector is the Computer Software Management and Information Center (COSMIC)®, located at the University of Georgia. COSMIC gets a continual flow of government-developed software packages and identifies those that can be adapted to secondary usage. The Center stores the programs and informs potential customers of their availability through a catalog and the NASA publication *Tech Briefs*.

COSMIC's library numbers more than 1,500 programs applicable to a broad spectrum of business and industrial applications. COSMIC customers can purchase a program for a fraction of its original cost. In most instances, users get a return many times their investment, even when the cost of adapting the program to a new use is included. Industry's acceptance has been extraordinary; the Center has distributed thousands of programs, some of which have made possible savings amounting to millions of dollars. Thus, COSMIC's service represents one of the broadest areas of economic benefit resulting from secondary use of technology developed by the government.

An example of how this technology aids industry is the use of a COSMIC program by Shell Oil Company, Houston, Texas. Known principally for its oil products, Shell is also one of the nation's largest manufacturers of chemical products. At several facilities, Shell produces chemicals for plastic products used in the manufacture of automobiles, housewares, appliances, film, textiles, electronic equipment and furniture.

In developing a new computer code for analyzing polymers—chemical compounds—researchers of Shell Development Company's Mechanical Engineering Section used a COSMIC program, developed by Jet Propulsion Laboratory, called VISCEL. Computerized analysis of structures made of lightweight plastic polymers provides feedback to polymer scientists as to how a proposed polymeric composite structure will perform. Such structures are employed in manufacture of parts for industrial users, including automotive companies, who seek decreased component weight but also require the strength equivalent of metal parts. The COSMIC program was used to insure the accuracy of the company's new computer code. Shell Development Company reported that there were no other programs available that could provide the necessary calculations.

Additional examples of how COSMIC programs are contributing to national productivity are described on the following pages. Other examples are listed elsewhere in this volume in the chapters on transportation and medicine.

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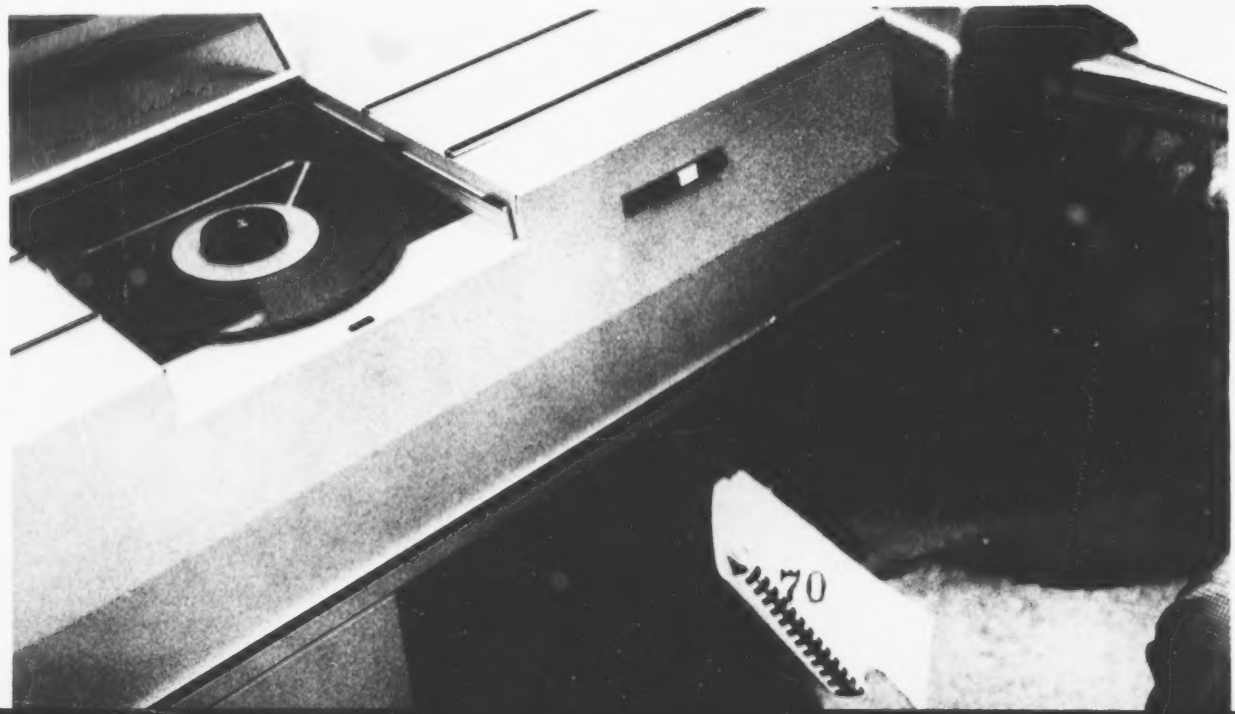
Equipment Analysis

At right, a military radio unit is undergoing vibration testing at Magnavox Government and Industrial Electronics Company, Fort Wayne, Indiana. In its research and development work, Magnavox has used the NASA Structural Analysis (NASTRAN)* computer program for vibration analysis of electronic equipment. The NASTRAN program, developed by Langley Research Center and supplied by NASA's Computer Software Management and Information Center (COSMIC), is used by many companies in hundreds of industrial applications. It is a general purpose program which mathematically analyzes a design and predicts how it will stand up under the various conditions of stress and strain it will encounter in operational service. This permits engineers to study the structural behavior of many different designs before settling on a final configuration.

At Magnavox, the NASTRAN program was originally used in the design stage of heavy aluminum fixtures for vibration testing. Electronic components, such as chassis and printed circuit boards, are mounted on the fixture and vibrated to determine the amount of vibration they can withstand. The NASTRAN program is also used to compare the resonant frequencies of the chassis and printed circuitry to predict whether failures may occur because of high vibration levels. Company engineers can then make design alterations to improve the equipment's vibration resistance. This method of analysis allows Magnavox to insure reliability and reduce the possibility of vibration-caused failure in such critical defense products as radios for aircraft and ground vehicles, airborne electronic warfare equipment, signal processors, sonobuoys and airborne antisubmarine warfare systems.

Magnavox uses another COSMIC software package—developed by Goddard Space Flight Center and called GENOPTICS, for General Purpose Optics Evaluation Program—in studies of hybrid optical systems. GENOPTICS was used in development of a Digital Optical Recorder, shown (bottom), which enables use of an optically-recorded disc to store and retrieve digital data. GENOPTICS is also used in company research and development of other optical systems. Magnavox reports that GENOPTICS provides more accurate results and that its use saved six man-months of time that would have been required to develop a comparable software package.

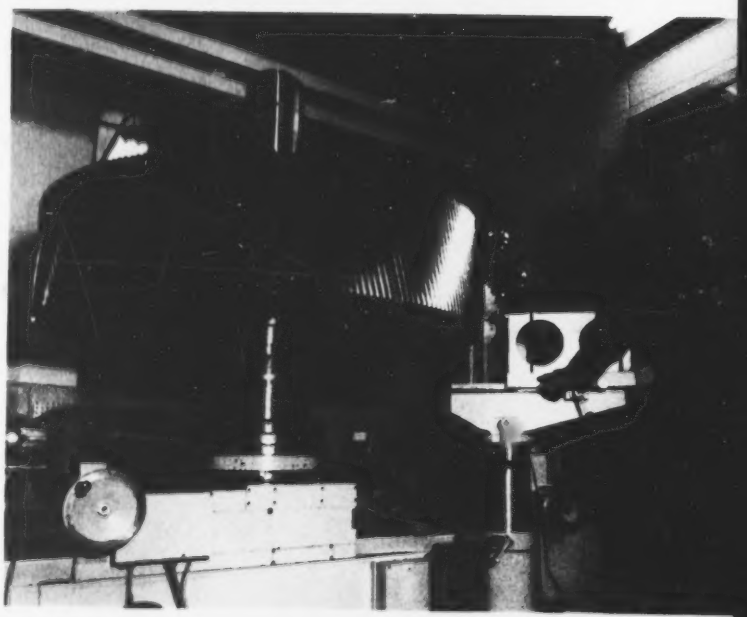
*NASTRAN is a registered trademark of the National Aeronautics and Space Administration.



Gear Drive Testing

Philadelphia Gear Corporation, King of Prussia, Pennsylvania produces a diverse line of power transmission products, including enclosed gear drives, fluid mixers and variable speed drives. The company specializes in custom units for unique applications, such as Coast Guard ice-breaking ships, steel mill drives, coal crushers, sewage treatment equipment and electricity-generating wind turbines. In the upper photo, the gear drive for a large wind turbine is undergoing final performance testing. The photo at right shows a quality assurance engineer using sophisticated equipment to measure tooth spacing of a large gear.

Philadelphia Gear has recently used two NASA COSMIC computer programs—one dealing with shrink fit analysis and the other with rotor dynamics problems—in computerized design and test work. The COSMIC programs, developed by Lewis Research Center, were used to verify existing in-house programs, in accordance with Philadelphia Gear's practice of insuring design accuracy by checking its company-developed computer methods against reliable procedures developed by other organizations.



Ship Design

In the top photo is the U.S. Navy's USS *Ticonderoga*, the first of the new CG-47 Class of guided missile cruisers equipped with the advanced Aegis fleet defense system, which automatically tracks hundreds of attacking aircraft or missiles, then fires and guides the ship's own weapons in response. The *Ticonderoga* is being built by Ingalls Shipbuilding Division of Litton Industries, Pascagoula, Mississippi. Ingalls, a leading designer and producer of Navy combat ships, oil drilling rigs, barges and other vessels for the offshore marine industry, has contracts for three additional CG-47 cruisers.

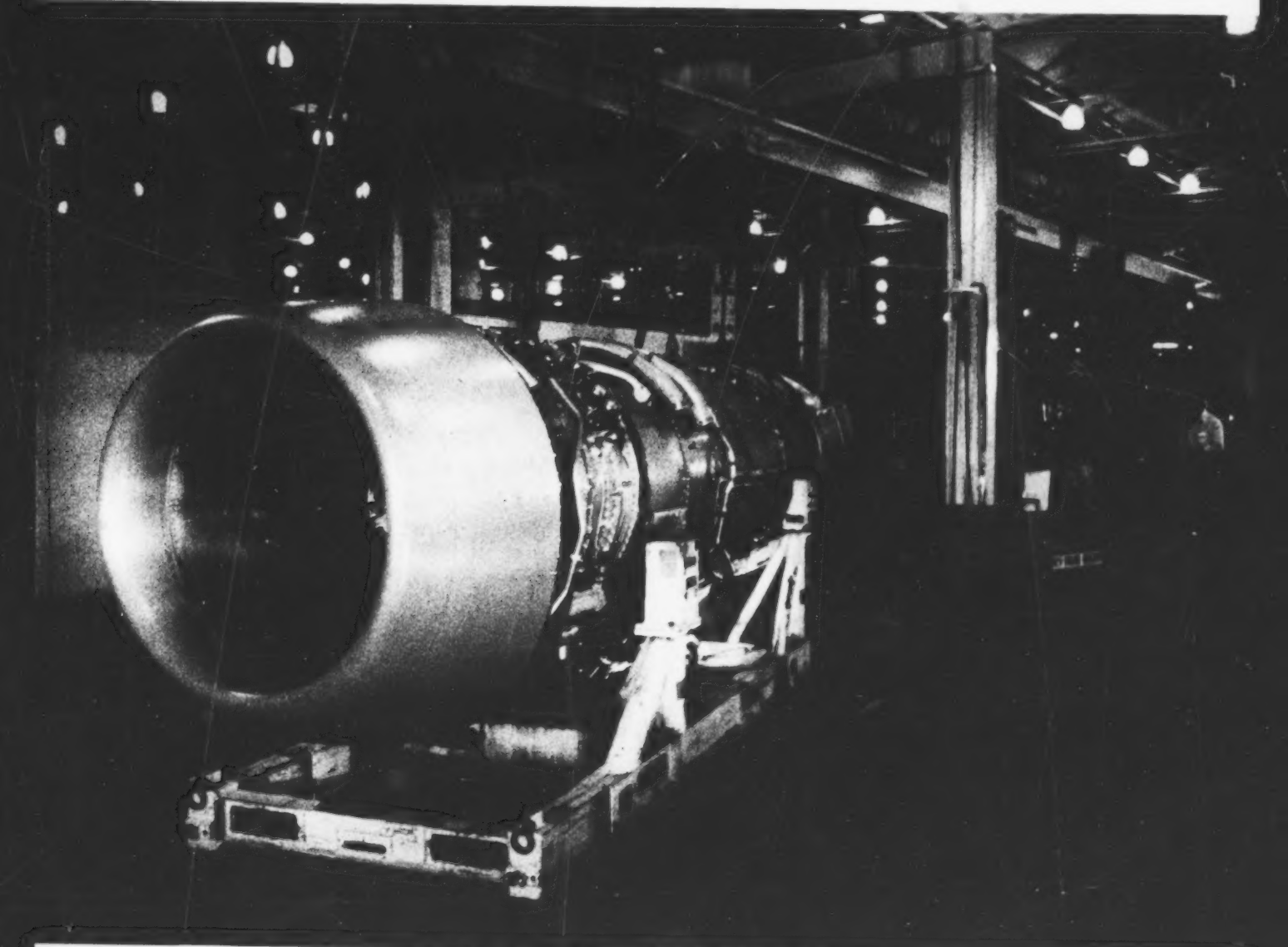
In constructing the ships, Ingalls used the NASA NASTRAN computer program, supplied to the company by NASA's Computer Software Management and Information Center (COSMIC). The NASTRAN program was also employed in another Navy/Ingalls project involving design and construction of four DDG-993 Kidd Class guided missile destroyers, one of which is shown above.

Nacelle Design

In the photo, production line workers at Rohr Industries, Inc., Chula Vista, California are installing engine nacelles for the McDonnell Douglas DC-9 jetliner; the nacelle assembly includes the cowling shown in foreground, the exhaust nozzle and other components, and the outer skin enclosing the whole engine. Although seemingly a simple component, the nacelle requires considerable research and development for each type of airplane because of complex airflows around the engine inlet and high pressures on the nacelle skin.

In its research work, Rohr Industries has made extensive use of a COSMIC computer program, developed by McDonnell Douglas under contract with Lewis Research Center, which defines the airflow field around turbofan engine nacelle inlets and cowls. The pressures on the nacelle skin are estimated for various flight conditions and this data helps stress analysts confirm the structural integrity of the nacelle design. Rohr estimates that use of the COSMIC program saved six man-months of programmer time necessary to develop alternative software.

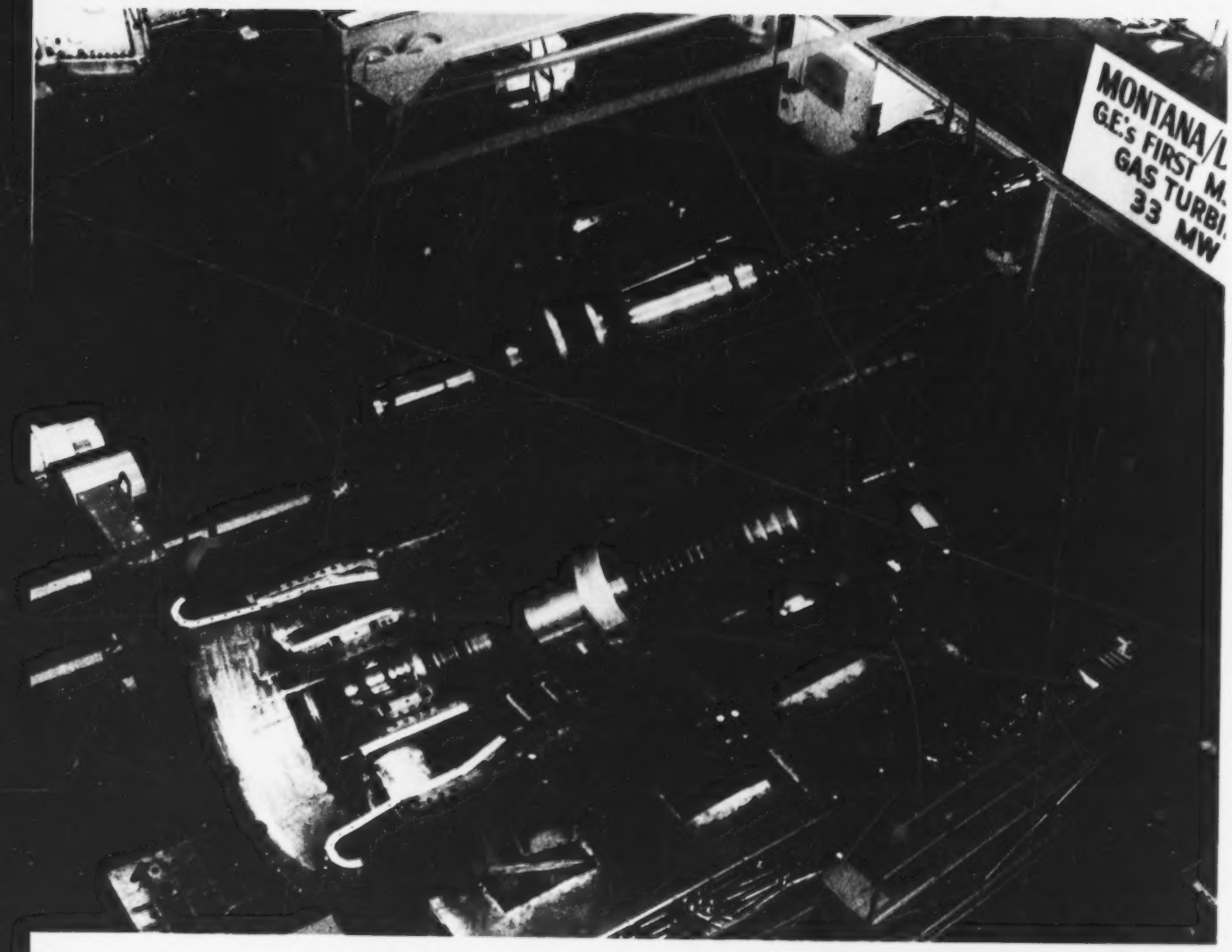
Rohr Industries, specialists in manufacture of nacelles, thrust reversers and other engine components, made use of the COSMIC program in nacelle work for such aircraft as the McDonnell Douglas DC-10, the French German Airbus, and the Boeing 727, 737 and 747 jetliners. Rohr also manufactures complete nacelles for military and business aircraft and is supplying nacelle components for the new Boeing 757.



Customer Service Programming

Illinois Bell Telephone, a subsidiary of American Telephone and Telegraph, provides communications equipment and assistance to Illinois business and residential customers. Located in Chicago, the company's Information Systems Department (photo) is responsible for computer systems development, including software for processing customer requests for new or additional service. Since 1979, the department's programming staff has been using a computer program from the NASA/COSMIC inventory called STRCMACS. Developed by Goddard Space Flight Center, the program provides aids and refinements for structured assembler language programming techniques and also offers "debugging" options.

Illinois Bell reports that its use of the COSMIC program has cut software development costs—perhaps as much as 10 percent—by reducing program maintenance and by allowing the department to bring other software into operation more quickly. The COSMIC program has also proved useful in company training of programming staff.



Turbine Blade Research

At General Electric Company's Energy Systems Program Department and Research and Development Center, Schenectady, New York, researchers are exploring a number of advanced methods for converting coal into electricity economically and in an environmentally acceptable manner. One approach, under study for several years, is called "pressurized fluid bed (PFB) combustion." In this concept, steam generated by tubes immersed in a fluidized coal bed drives a steam turbine, while the hot gases created by coal combustion are used to drive a gas turbine. A key technical problem is erosion of blades in the gas turbine, caused by impacts of particles in the combustion gas stream.

Under a contract with the New York State Energy Research and Development Authority, GE's Energy Systems Programs Department has used a COSMIC computer program—developed by Lewis Research Center—in assessing the problem of blade erosion in a PFB environment. Data provided by the COSMIC program and an associated program helped company engineers determine gas velocities and ultimately the velocities of the particles striking the blades, calculations necessary for predicting blade erosion and potential damage. The assessment resulted in a new estimate for the allowable dust load for a modern heavy-duty gas turbine. In the photo is a rotor for a GE heavy-duty gas turbine, one of two types manufactured at the company's Greenville, South Carolina plant which may be used with a PFB system in the future.

A line of biomedical devices based on aerospace expertise leads a sampling of spinoffs in the field of medicine

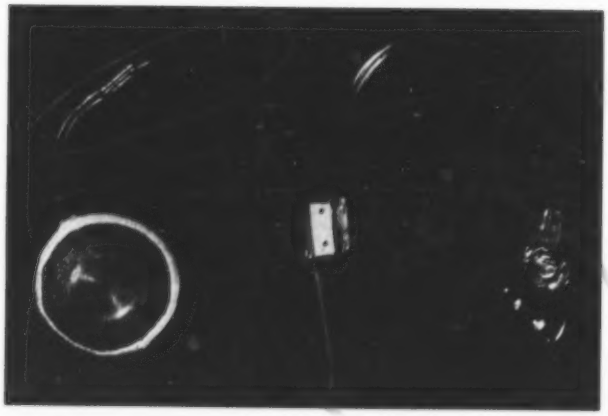
Space Technology for Medical Aids

Among the earliest contracts awarded in the Apollo lunar landing program was one to Parker Hannifin Corporation, Cleveland, Ohio, the world's primary supplier of fluid system components. Parker's assignment was to develop and produce equipment for controlling the flow of propellants into the mammoth engines of the Saturn moonbooster. That marked the beginning of the company's long association with NASA and the U.S. space program; today, Parker is supplying the huge valves that control propellant flow from the Space Shuttle's external fuel tank to the engines of the Shuttle Orbiter.

During the intervening two decades, Parker worked on many other space projects, often producing equipment at the opposite end of the size spectrum—for example, subminiaturized pressurization systems and small attitude control valves for satellites. A development of particular note was the "peanut valve," named for its small size. These miniature controls were part of the experiment packages in two NASA Viking spacecraft that landed on Mars in 1976. In a search for life experiment, automated equipment on the Viking Landers scooped up Martian soil samples and introduced nutrients to see if the nutrients were absorbed by some form of organism in the soil. The peanut valves, which Parker officials call the company's "crowning achievement" in miniaturizing fluid controls, metered the nutrients into the soil samples in precisely controlled amounts.

The broad expertise the company acquired in its aerospace developments is now being put to work in an entirely different field. Recently, Parker's Aerospace Group formed a Biomedical Products Division, located in Irvine, California, to apply aerospace technology, particularly miniaturized fluid control technology, to devices for medical treatment.

Parker's biomedical effort began in 1977. Recognizing the company's special expertise in miniature systems, NASA asked Parker to participate—with Marshall Space Flight Center and Rochester (New York) General Hospital—in the development of an implantable artificial sphincter for control of urinary incontinence. The Parker-developed pressure control valve and the artificial organ have been successfully tested in animals and human tests are planned for this



year. Parker has joined with Medical Engineering Corporation, Racine, Wisconsin, to commercialize the development. Additionally, the system is being further developed for control of fecal matter in persons who have undergone certain kinds of surgery.

The company's peanut valve experience provided an ideal technology base for another biomedical project. In 1979, Parker was invited by NASA to join a team—composed of Johns Hopkins University's Applied Physics Laboratory, Goddard Space Flight Center and several commercial firms—which was developing a Programmable Implantable Medication System (PIMS) for continuous, computer-directed delivery of medication—insulin, for example—within a patient's body. Parker's key contribution was a tiny pump capable of metering medication to target organs in precise doses—about a millionth of a liter at a time. Animal tests of the PIMS system have been conducted and clinical testing should begin late this year.

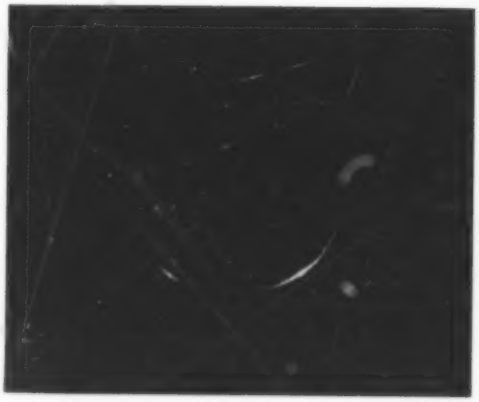
The company's work on PIMS inspired development of a related programmable medication device for external, rather than implantable, use. Called Micromed™, it is smaller than one previously available device; it is in initial use by diabetics who are dependent on insulin.

The Biomedical Products Division has also applied its fluid handling expertise to a drugless therapy system called Cryomax™ for treatment of such disorders as rheumatoid arthritis and lupus. Developed in cooperation with the Cleveland (Ohio) Clinic, Cryomax is a plasma filtration system which removes from the blood certain substances believed to contribute to progression of these diseases.

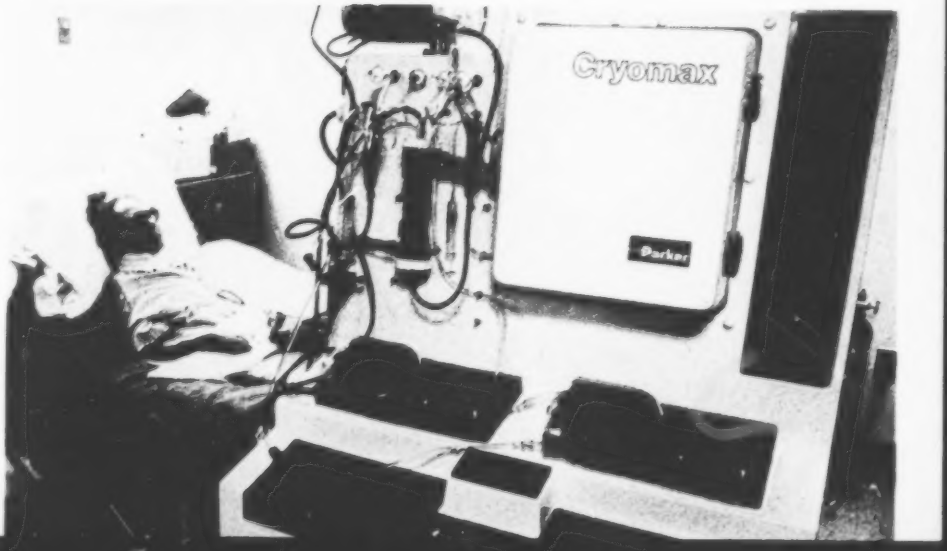
™ Micromed and Cryomax are trademarks of Parker Hannifin Corporation

In addition to its space work, Parker Hannifin Corporation has long been a leading supplier of actuators which position the flight control surfaces of commercial transport aircraft. This technology, in miniature form, is being applied to new devices designed to aid surgeons in arthroscopic procedures, which allow knee and other surgery without protracted recuperative time.

Some of Parker Hannifin's new biomedical devices trace their genesis directly to technology developed for NASA; others do not. But, says the company, it was NASA's encouragement and guidance that provided the impetus for its entry into a new field where its technology and expertise can be applied for human benefit.

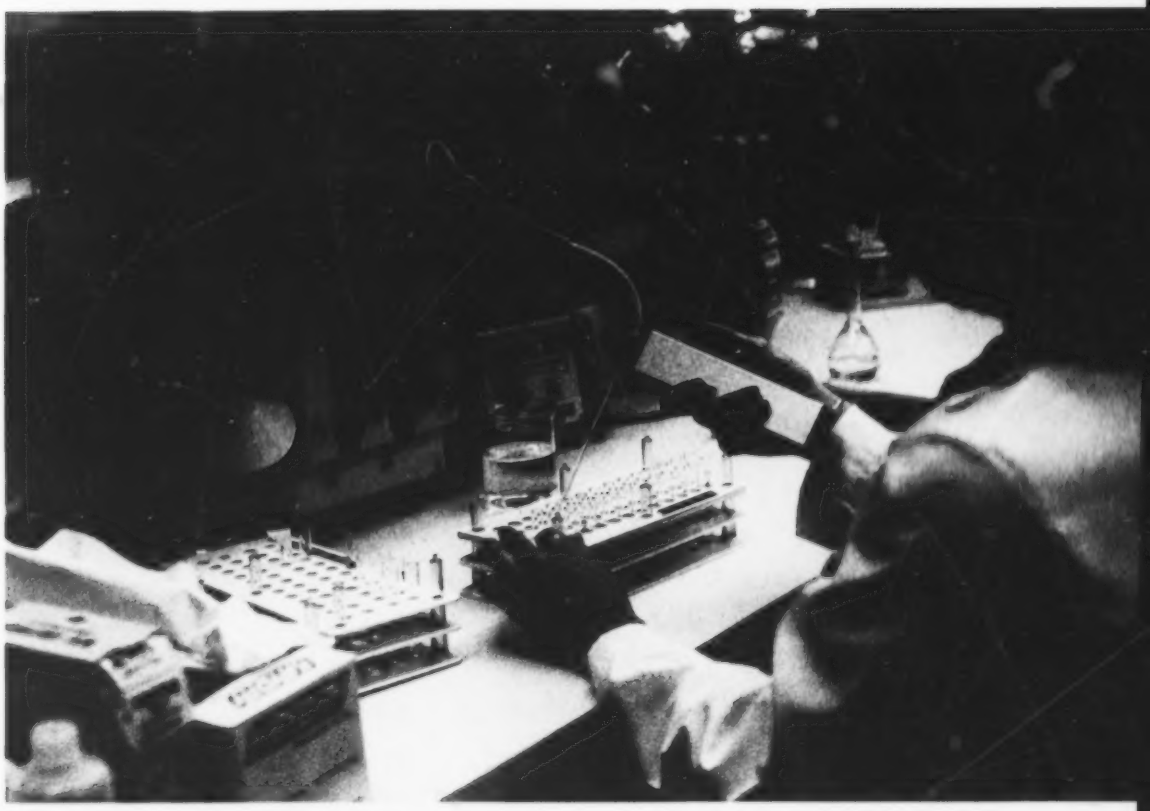


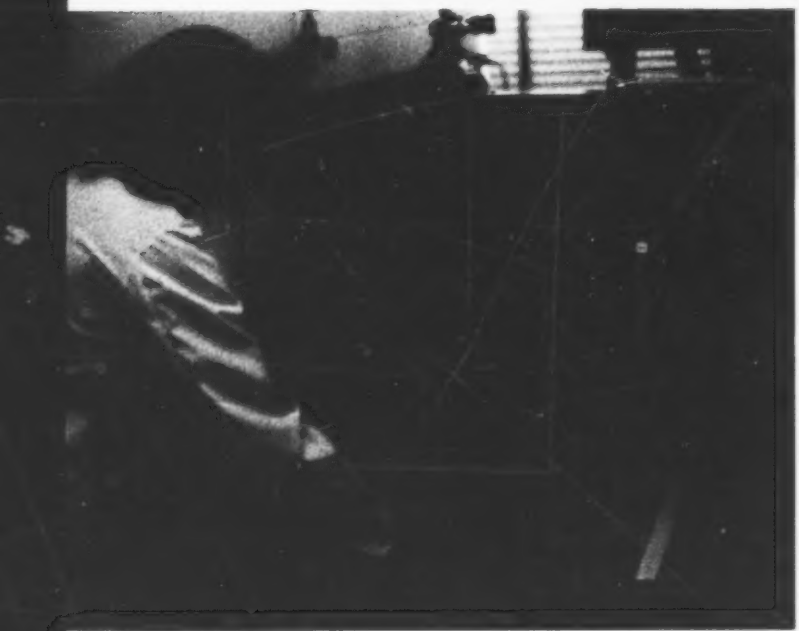
Parker Hannifin Corporation, a large industrial firm long identified with the U.S. space program, has created a Biomedical Products Division (opposite page) to apply its aerospace-acquired expertise to development of medical devices. Among the company's products, being developed in cooperation with other organizations, are an artificial sphincter for control of urinary incontinence (top); an implantable device about the size of a woman's compact for continuous delivery of medication (above); an external medication delivery system now in use by insulin-dependent diabetics (left); and a blood filtering system for treatment of such disorders as rheumatoid arthritis and lupus (below).



Communicable Disease Research

The Centers for Disease Control (CDC), Atlanta, Georgia, is one of six major agencies of the U.S. Public Health Service. Among a number of other responsibilities, CDC conducts a national program to combat many types of communicable diseases that are spread from person to person or by animals, insects and the environment. CDC's Clinical Chemistry Division is





active in many areas of this effort, including development and evaluation of techniques, materials, chemical reagents and devices used in public health laboratories. In one phase of its work, the Division makes regular use of a program called FITLOS, supplied by NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia (see page 66). FITLOS is used for analyzing data from radioimmunoassays, which involve testing human body substances—such as hormones—to provide information on how deficits or excesses of these substances affect a body's ability to ward off disease.

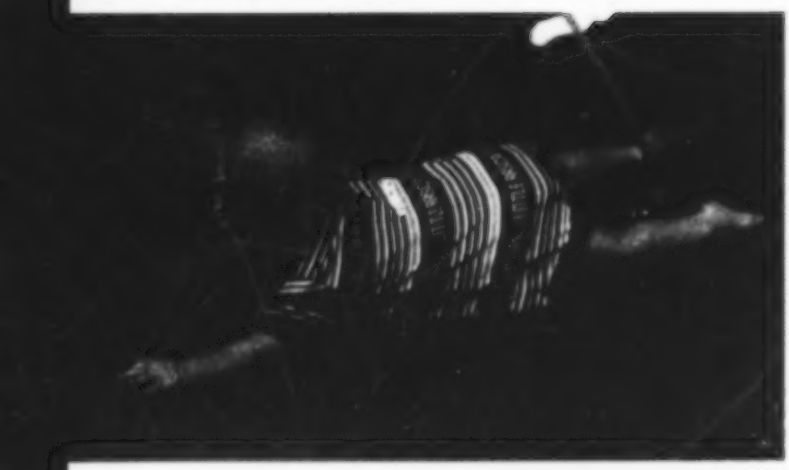
Above, a CDC chemist is preparing a hormone sample for use in a radioimmunoassay. At left, the chemist is working at a liquid scintillation counter; the counter measures the amount of radioactive material in the sample, a basis for determining the patient's deficit or excess amount of hormone. The counter's data is analyzed by the FITLOS program. FITLOS data, in turn, aids in establishing reference methods which can be used by hospitals and other health laboratories in their radioimmunoassays. Use of COSMIC's FITLOS enabled CDC to avoid the cost of designing and developing an entirely new program.

® COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Medical Products Research

An example of the technical assistance provided industry and government clients by NASA's Industrial Applications Centers is research work performed for Ventrex Laboratories, Inc., Portland, Maine by the New England Research Application Center (NERAC) located at the University of Connecticut. Ventrex develops, manufactures and markets a line of medical diagnostic assays (right) based on biochemical techniques, in particular immunochemical techniques—those concerned with tests of the body's immune system, its first line of defense against disease. Ventrex products are sold worldwide to hospitals and medical laboratories for use in testing blood samples and other biological fluids; analysis of a patient's body fluids, compared with normal values, aids a physician in confirming or otherwise diagnosing a suspected disease condition.

Since Ventrex Laboratories' incorporation in 1976, the company's research and development group has benefited from the information search and retrieval service provided by NERAC. The company is continually looking for innovative test methods—ranging from drug detection to cancer testing—that have long range market potential for Ventrex products. NERAC helps by conducting computer searches for applicable data available from government agencies, medical conferences, pharmaceutical industries and other sources of chemical/biological information. NERAC's rapid information retrieval has proved invaluable, the company says, and permitted large scale savings. The NERAC service was particularly important in development of a new product in the company's Ventre/Sep line, which is used in radioimmunoassays—testing with radioactive tracers to measure body substances which are present in blood in minute concentrations yet have major influence on a patient's clinical status. Below, a technician is preparing a component substance to be used in a Ventre/Sep assay.



Crawling Aid

Learning to crawl, the first step toward full human mobility, is generally taken for granted. But some brain-injured children are unable to crawl, due to the problems of weight-bearing and friction, caused by gravity. For several years, the Institutes for the Achievement of Human Potential, Philadelphia, Pennsylvania sought a method of reducing the restrictions imposed by gravity. A variety of devices were tested; some offered a minor degree of help, most failed. Now, however, through a collaborative effort by the Institutes and Ames Research Center, an effective crawling aid has been developed. Fifty of the devices have been built and are being used as part of an overall rehabilitation program conducted by the Institutes.

Shown in the accompanying photos, the device is known as the Vehicle for Initial Crawling (VIC); the acronym is a tribute to the crawler's inventor, Hubert "Vic" Vykukal, an Ames engineer who applied technology originally developed for frictionless systems designed to simulate the motions of satellites in space. The VIC is a rounded plywood frame large enough to support the child's torso, leaving arms and legs free to move. On its underside are three aluminum discs through which air is pumped to create an air-bearing surface that has less friction than a film of oil. The upper side contains the connection to the air supply and a pair of straps which restrain the child and cause the device to move with him.

The intent is to recreate the normal neurological connection between brain and muscles which was impaired by the brain injury. When the child makes a movement that causes him to slide forward on the frictionless surface, he receives positive mental "feedback" that encourages him to repeat the movement. Over repetitive use of the device, he develops his arm and leg muscles as well as coordination. In one test case, a four-year-old who once needed 16 hours to crawl a single foot was able, after a month on the device, to crawl 16 feet on his own in 25 minutes. In another, a 10-year-old who could crawl only 13 feet in eight hours managed 140 feet in four hours after seven months on the VIC. Children are given alternating therapy, with and without the VIC, until eventually the device is no longer needed. An Institutes official states that the VIC is not expected to solve the problems of all immobile children, but thousands could benefit from the device.

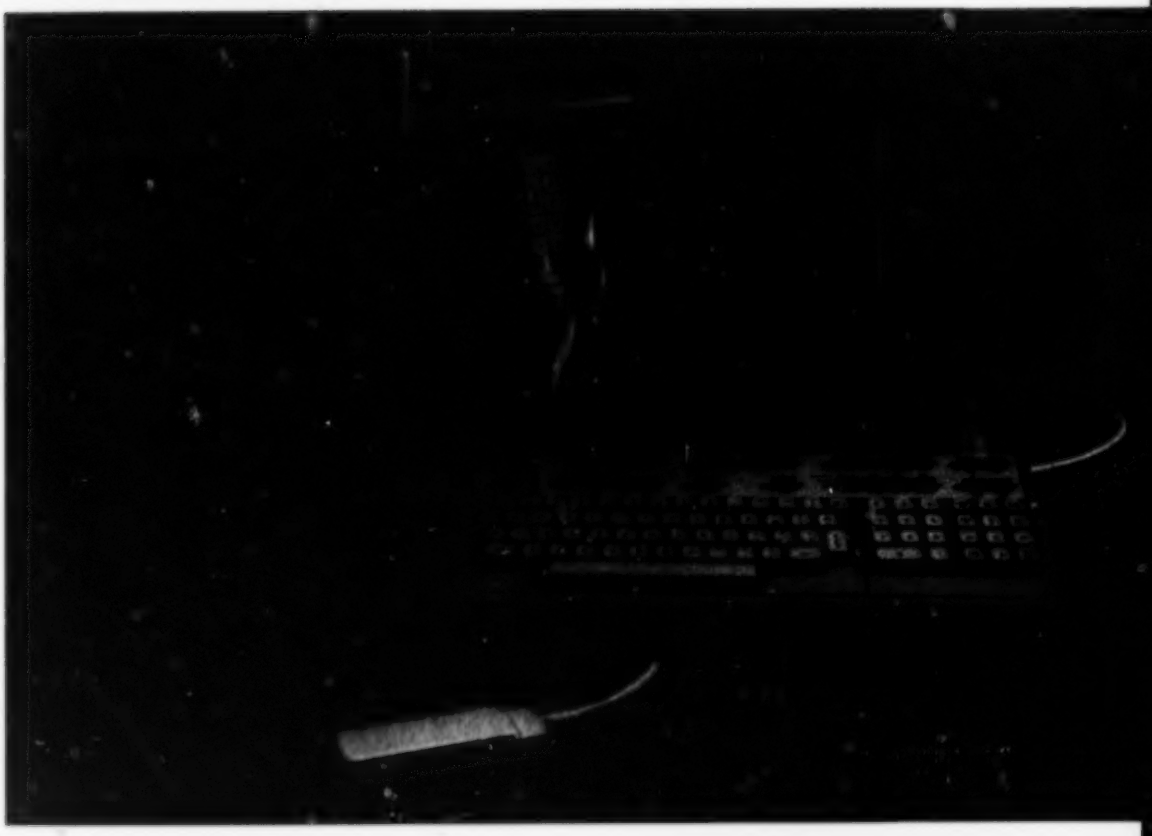
Portable Medical System

In the photo above, a paramedic is administering emergency aid to a heart attack victim, using a Portable Medical Status and Treatment System (PMSTS) that incorporates NASA astronaut-monitoring, electronic circuitry and microminiaturization technologies. Developed by Narco Scientific Bio-Systems Division, Houston, Texas, the system is designed for use in remote areas where considerable time may elapse before a patient can be transported to a hospital. First units were delivered to the Department of Transportation last year and tested in two types of medical emergency environments: one in a rural Pennsylvania community and another aboard a U.S. Coast Guard rescue helicopter operating along Florida's Gulf Coast.

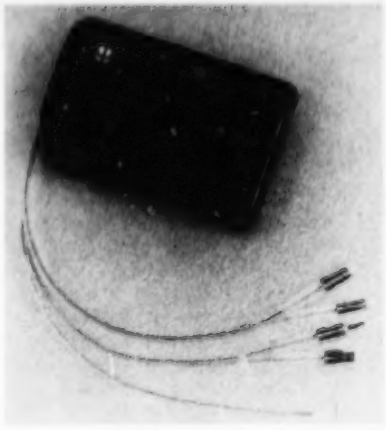
Key elements of the battery-powered PMSTS include a vital signs monitor and a defibrillator. The microprocessor-based monitor, which can operate for six hours, features a five-inch scope, a data recorder and membrane-switch controls. The scope provides a display of pulse rate, temperature, blood pressure and respiration rate, along with status information, including heart rate and respiration rate alarms. The defibrillator delivers an electrical shock to restore rhythmic heartbeat after fibrillation, an erratic heart action in which the organ loses its ability to pump blood. In the photo, the attendant is applying defibrillator "paddles" which contain controls allowing selection of six different energy levels. The system includes a 10-channel radio with two-way voice communication and the capability to transmit vital signs to a distantly-located physician, who can perform diagnosis and relay treatment instructions to the attendant at the scene of the emergency.

Narco has also developed a companion system, called Porta-Fib III (below), designed for use in a hospital environment. In this unit, the radio and some of the PMSTS monitoring features which would not be required in a hospital have been eliminated, and technologies for the defibrillating and display functions have been refined and expanded. Porta-Fib III is expected to be introduced this year.

The PMSTS and Porta-Fib III are offshoots of an earlier NASA project known as the Physician's Black Bag, a portable monitoring/treatment unit developed for Johnson Space Center by Telecare, Inc., a company later acquired by Narco. In developing PMSTS and Porta-Fib III, Narco incorporated some of the Black Bag technology and further developed the system to include additional functions, displays and controls.



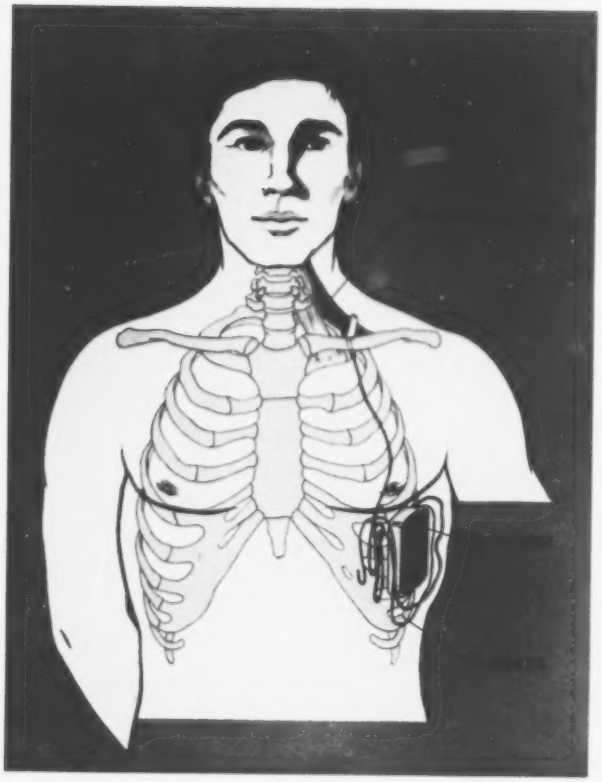
Human Tissue Stimulator



Shown above are the various components of a system for treatment of chronic pain and involuntary motion disorders by electrical stimulation from a device implanted in the body. Called the Human Tissue Stimulator (HTS), it was developed by Pacesetter Systems, Inc., Sylmar, California, in cooperation with the Applied Physics Laboratory of Johns Hopkins University, Howard County Maryland. Sponsored by Goddard Space Flight Center, the system is based on Goddard-developed technology employed in NASA s Small Astronomy Satellite-3. The HTS incorporates a nickel cadmium battery, telemetry and command systems technologies of the same type as those used in the satellite, reduced to microminiature proportions so that the implantable element is the size of a deck of cards. In contrast to earlier stimulating devices—which require cumbersome, externally-carried power packs or which have very limited lifetimes—the HTS is a totally implantable system with a number of additional technological advances.

At right is a close-up view of the implantable stimulator, which includes a tiny rechargeable battery, an antenna and electronics to receive and process

commands and to report on its own condition via telemetry, a wireless process wherein instrument data is converted to electrical signals and sent to a receiver where the signals are presented as usable information. The HTS sends electrical pulses through wire leads to targeted nerve centers or to particular areas of the brain; this provides relief from intractable pain or arrests involuntary motion. The nickel cadmium battery can be recharged through the skin so that frequent surgical replacement is not required.



The first two HTS units were implanted last year. The initial operation—conducted under the direction of Dr. Irving Cooper, Director of the Center of Physiologic Neurosurgery at Westchester County Medical Center, New York—involved a female patient who had severe involuntary movement disorders associated with multiple sclerosis. Several hours after surgery, the stimulator was applied to a part of the thalamus, a small region of the brain. The patient's tremors vanished—although moments earlier she had been unable to guide a cup of coffee to her lips.

The second HTS was implanted by Dr. Donlin M. Long, Chairman of the Department of Neurosurgery at Johns Hopkins School of Medicine, Baltimore, Maryland. The patient had for several years suffered excruciating pain in his left arm, caused by a wrist injury in a fall. Implanted under the left arm (left), the HTS was connected by the wire leads to electrodes on the brachial plexus, a group of nerves that link the spinal cord with the injured arm. When the stimulator was activated, the patient reported immediate relief from the pain. The photo below shows Dr. Long in post-surgery consultation with the implantee. The console next to the physician is used to monitor and program the implanted HTS; the controller Dr. Long is holding enables him to turn the stimulator on and off or to alter the character and strength of the electrical impulses.

Although the initial implants were successful, extensive testing is required before the HTS can be made available for general use. Within the next few years, Pacesetter Systems expects to produce commercial programmable neural stimulators based on the HTS.

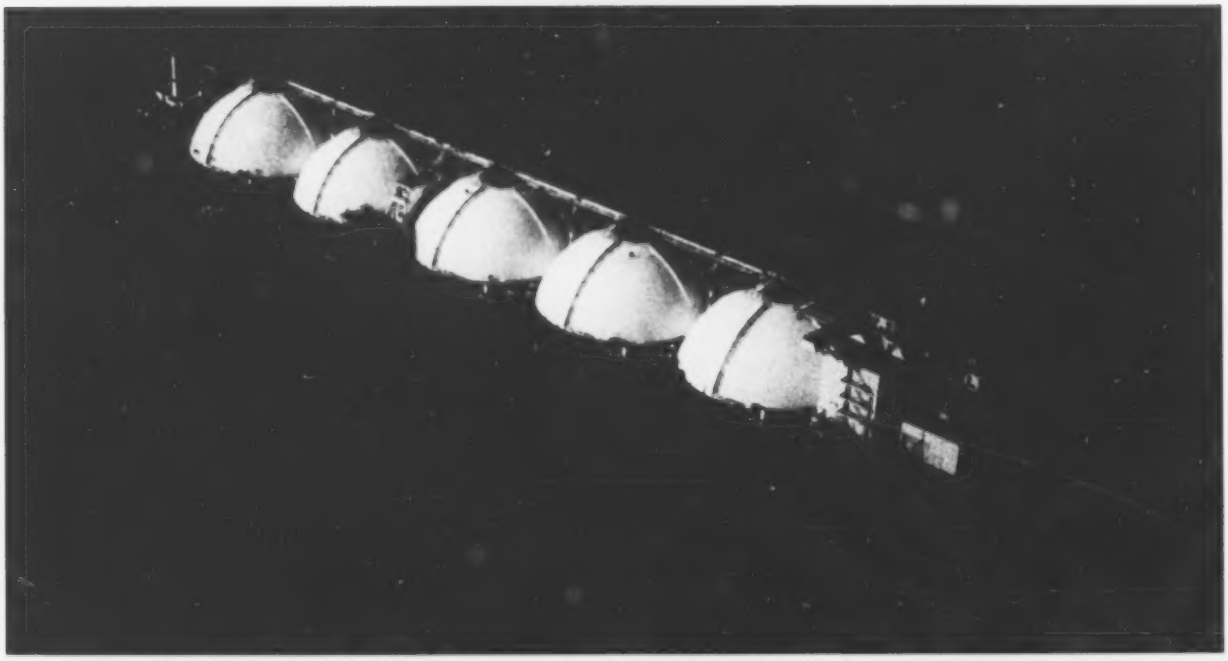
Spinoff systems for monitoring supercold fluids highlight technology transfers in the field of industrial productivity

From Lift-Off to Light-Off

The largest and heaviest element of the Space Shuttle is the 154-foot long external fuel tank, which feeds 1.5 million pounds of propellants to the Shuttle's three main engines during ascent to orbit. The propellants are "cryogenics" which must be maintained at supercold temperatures—minus 434 degrees Fahrenheit in the case of the liquid hydrogen fuel and minus 326 degrees for the liquid oxygen oxidizer. The engines gulp the huge tank dry in just over eight minutes—so the tank loses weight at the rate of almost 100 tons a minute.

It is essential that the Shuttle's computers be informed of these rapid changes in vehicle weight. The computers must also know when the tank runs dry, so they can shut down the engines. These jobs, crucial to mission success and crew safety, fall to a highly precise measurement system, necessarily sophisticated because of the cryogenic nature of the propellants. The system must take into account density, temperature, pressure and the specific configurations of the two separate containers housing the fuel and the oxidizer. These factors are determined by a number of sensors, whose inputs are fed to a signal conditioner and processed for accurate, continuous readouts of

Carrying cargoes valued at $15 million per shipload, tankers like the one below transport approximately 550 billion cubic feet of liquefied natural gas (LNG) a year. A space-spinoff, Simmonds Precision's LNG measurement and monitoring system aids accurate financial accounting and enhances crew safety. At left, engineers examine a segment of a 120-foot sensor employed in the measurement process.



propellant status from liftoff to engine shutdown.

The Shuttle's propellant measurement system is produced by Simmonds Precision, Tarrytown, New York, an old hand at monitoring space-use cryogenics; the company built similar equipment for the Apollo spacecraft and the later Skylab manned orbiting research station. Simmonds also has extensive experience in fuel management systems and other equipment for military and commercial aircraft. The company's aerospace-acquired expertise has led to a number of non-aerospace spinoffs which prompted formation of a separate corporate entity, the Industrial Controls Division.

An example of a Simmonds spinoff is a "custody transfer" system for measuring and monitoring liquefied natural gas (LNG). A cryogenic, LNG is transported aboard large tankers at minus 260 degrees Fahrenheit. The value of a single shipload may reach $15 million, so accurate measurement of the LNG transferred to and from the ship is financially important. Additionally, proper monitoring of the volatile LNG aboard sea-going vessels is vital to crew safety. Applying its aerospace-developed cryogenics measurement technology, Simmonds has provided custody transfer systems for 10 LNG tankers—built by Quincy (Massachusetts) Shipbuilding Division of General Dynamics Corporation—which are operating between Indonesia and Japan.

Simmonds has also provided measurement systems for several liquefied petroleum gas (LPG) production and storage installations, for example, an Atlantic Richfield Indonesia offshore terminal in the Java Sea. Built on a barge, the terminal receives, liquefies, stores and transfers LPG to ships for worldwide distribution; Simmond's

Among other aerospace spinoffs developed by Simmonds Precision are an advanced ignition system for industrial boilers (left) that offers savings of millions of gallons of fuel, and a computer-based monitoring and control system for improving safety and reliability in electrical utility applications (below).

instrumentation is used in a number of these operations. The same type of system is used for land-based LPG inventory and control system in the state of Washington.

Another adaptation of aerospace technology to the industrial marketplace involves the application of jet engine ignition know-how to conservation of fuel in industrial boilers. The energy savings result from the fact that these advanced igniters can "lift off" heavy industrial fuels without a preliminary ignition step. This is particularly important in the case of pulverized coal, an increasingly popular fuel in industrial boiler applications. Conventional burners require that a fuel with a lower ignition point—such as oil—be lighted first; the burning oil, in turn, fires the coal. With a Simmonds industrial ignition system, the coal is ignited directly and the preliminary burning is eliminated.

In still another industrial sector spinoff, Simmonds produces a line of aerospace-derived safety systems for nuclear and non-nuclear electrical power plants. These systems employ minicomputer technology to monitor continuously and display critical operating variables; they automatically shut down the plant when unsafe conditions are detected.

Cool Vest

In some industrial environments, very high temperatures limit the time an employee can work and this reduces company productivity. An example: in the containment area of a nuclear electric utility, temperatures run as high as 160 degrees Fahrenheit; technicians who must enter the area to make repairs can tolerate the heat for only short periods, which prolongs the repair time. Another example: employees of a chemical plant in Texas wear "slicker suits" as protection against acids and caustic chemicals made at the facility; wearing this equipment while working outdoors at temperatures up to 100 degrees, a worker could suffer dehydration.

A productivity-enhancing answer to these problems is being manufactured by ILC Dover, Frederica, Delaware, a division of ILC Industries, Inc. Called the Cool Vest™, it is a lightweight cooling garment designed to eliminate the harmful effects of heat stress; the vest increases tolerance time in hot environments by almost 300 percent. It incorporates technology developed by ILC Dover in the design, development and manufacture of space suits for the Apollo, Skylab and Space Shuttle programs.

In the photo, the Cool Vest is worn by a technician of the Baltimore Gas & Electric Company facility at Calvert Cliffs, Maryland. Made of urethane-coated nylon, it works to keep the body cool, circulating chilled water throughout the lining by means of a small battery-powered pump. A pocket—worn at back in this photo—houses the pump, battery and the coolant, which can be ice or a frozen gel; a valve control allows temperature regulation. The vest may be worn externally as shown or under a protective garment. The version pictured is self-contained and portable for unrestrained movement; an alternative version, for use where extended mobility is not required, has an umbilical line attached to an external source of coolant, such as a standard water tap. Customers report that the Cool Vest pays for itself in increased productivity and provides a bonus in improved employee morale.

ILC Dover is producing a related garment based on the same technology. Called the Vari-Temp Tube Suit, it is a form-fitting undergarment with a network of soft, flexible tubing through which either cooling or warming fluid is circulated to maintain comfortable body temperature. Liquid from a permanent water supply or a portable closed-loop system enters the suit, flows around the body and exits through an umbilical line.

™ Cool Vest is a trademark of ILC Industries, Inc.

Bank Record Processing

Barnett Banks of Florida, Inc., headquartered in Jacksonville, operates 150 banking offices in 80 Florida cities. An affiliate, Barnett Computing Company, provides telecommunications and data processing services for the internal operations of the various banking offices, which have computerized systems for processing deposits or withdrawals in checking/savings accounts and for handling commercial and installment loan transactions.

In developing a network engineering design for the terminals used in record processing, Barnett Computing used a computer program from the inventory of NASA's Computer Software Management and Information Center (COSMIC)®, which routinely supplies such programs to industrial and commercial firms in the interests of national productivity (see page 66). Use of COSMIC's STATCOM (State Criminal Justice Telecommunications Network Optimization) program gave Barnett a reliable network design tool and allowed the company to avoid the cost of developing new software.

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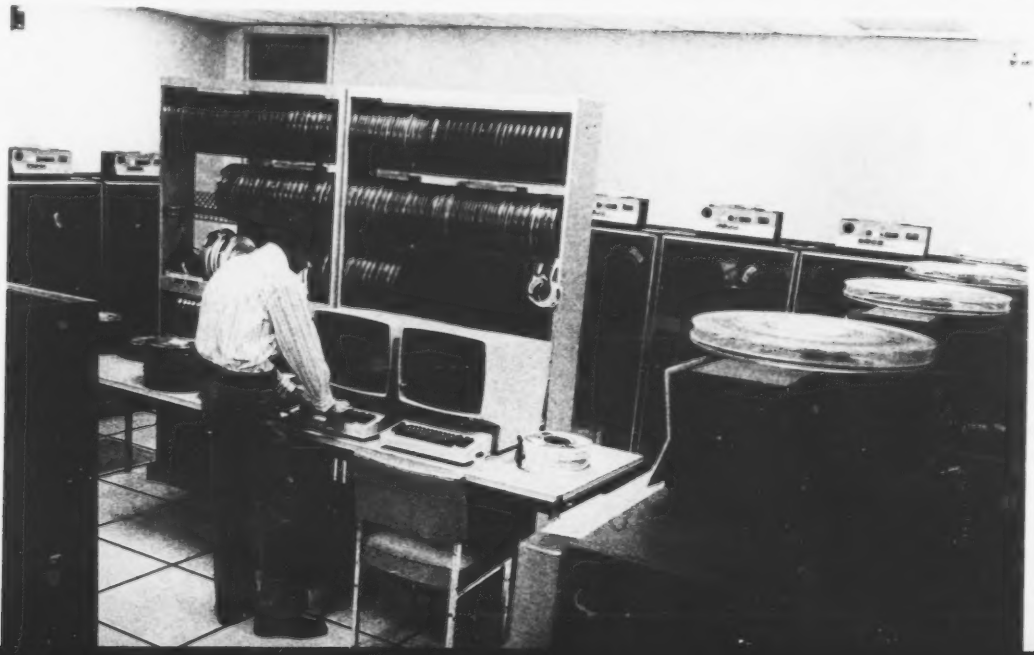
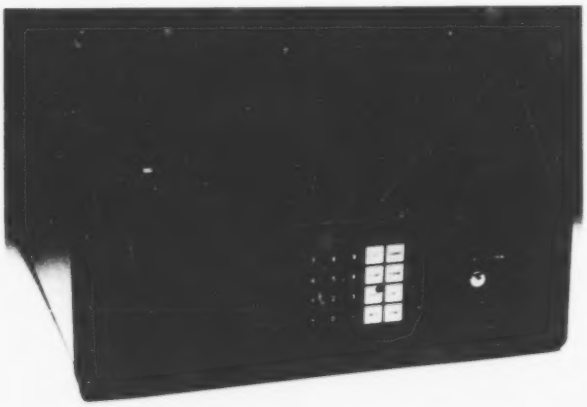


Pressure Measurement

The module pictured below is a system designed to increase productivity in industrial processes where there is need for making multiple pressure measurements quickly and with high accuracy. Called the DPT 6400, it is produced by Pressure Systems Incorporated (PSI), Hampton, Virginia, a spinoff company whose whole product line is based on NASA technology developed for wind tunnel instrumentation.

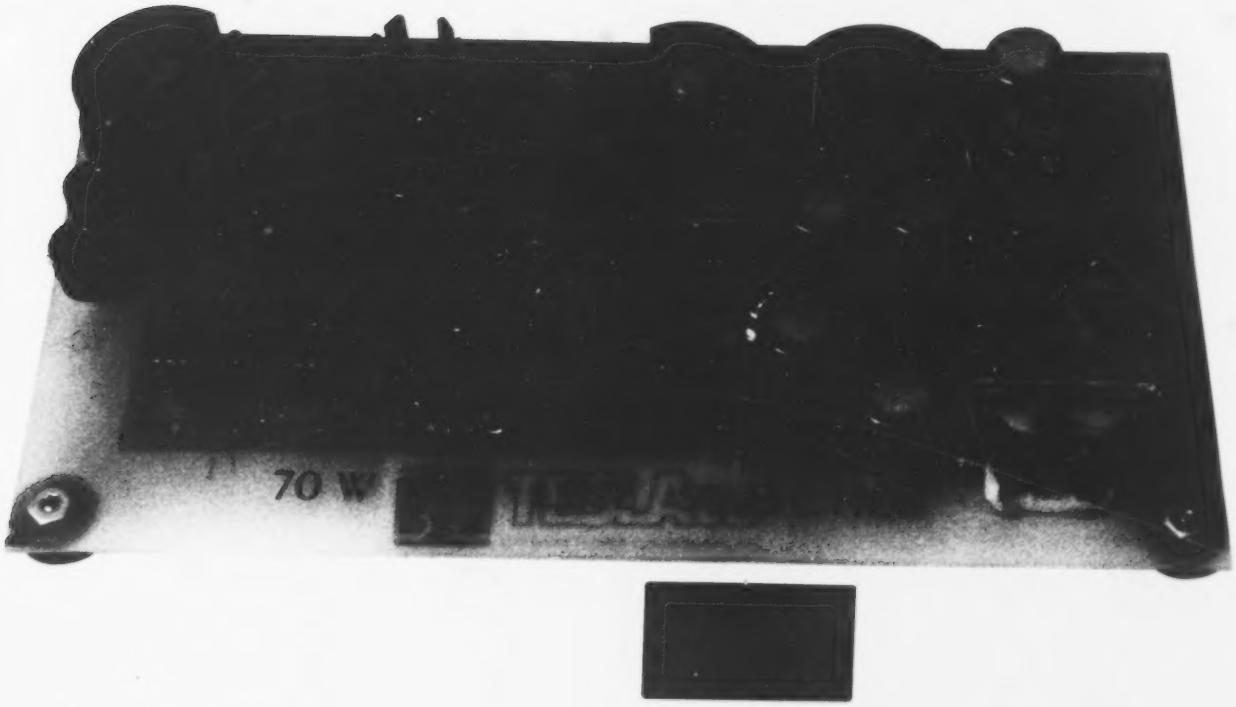
The DPT 6400 has application in controlling industrial processes in plants that are being upgraded to automated status. Many plants use instrument air "loops" to control the individual valves and actuators throughout the plant; in some plants, there are as many as 3,000 loops. In order to automate such plants, the pressures at the many loops must be measured, converted to digital information, and transmitted to the



plant's process control computer. The DPT 6400 serves that function; by employing solid-state pressure-sensing transducers whose errors are automatically corrected by a microprocessor, it is capable of highly accurate pressure measurements; above, the digital reading (in red) indicates the channel number and the pressure, in pounds per square inch, at the loop being sensed. The basic DPT 6400 has 64 channels, but the system can be expanded to 256 channels by addition of "slave" units.

The DPT 6400 is an outgrowth of electronically scanned pressure (ESP) technology, which was developed at Langley Research Center to meet a need for higher data rates and high accuracy in measuring pressures at a great many points in a wind tunnel; ESP modules provide as many as 20,000 readings a second. At upper left, a Space Shuttle Orbiter model is undergoing wind tunnel testing at Langley for analysis of the shock wave visible in the photo; in tests like this, ESP modules measure the pressure at various points on the module. Along with other test data, ESP readings are displayed in the control room (left); the ESP model is above the technician's head.

Now president of PSI, Douglas Juanarena was an instrument design engineer at Langley and one of the developers of ESP. In 1977, he obtained a NASA license for the technology and formed PSI. In addition to its new industrial-use DPT 6400, the company supplies pressure measurement instrumentation for use in wind tunnels, jet engine test stands and aircraft flight testing; customers include government and aerospace industry laboratories in the U.S. and abroad.



Power Supply Unit

In electronics terminology, power processing is the use of circuitry to change electric power from one form to another. A spacecraft, for example, usually derives its electric power from solar cells. This is "unregulated" direct current (dc) power which must be processed, converted to regulated, or steady, dc voltage for powering the spacecraft's instruments. In the early days of space flight, power processing switcher converters were heavy, cumbersome and inefficient devices. Over years of research, lighter switchers were developed, but they were still not highly efficient—until 1979, when California Institute of Technology scientists made an important breakthrough in research sponsored by Lewis Research Center.

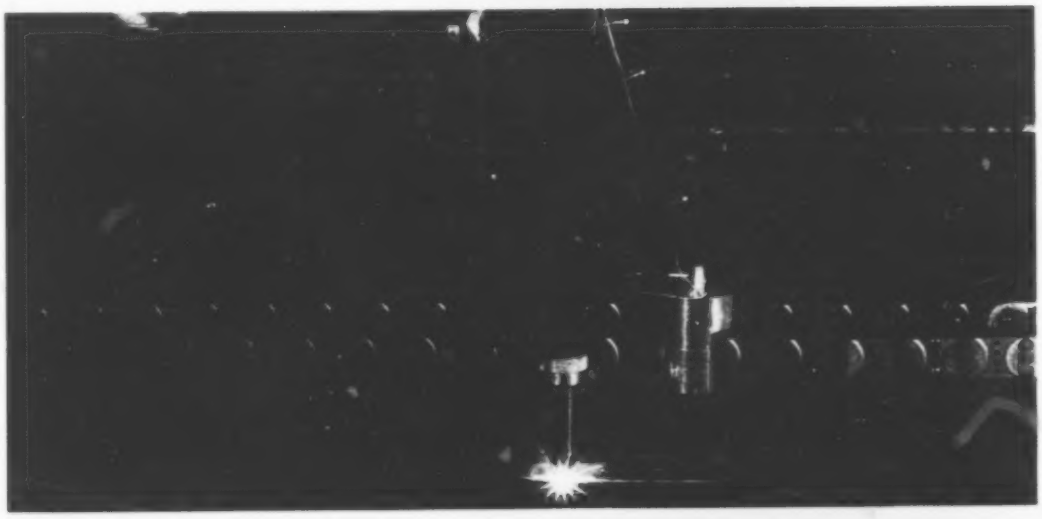
The result was the Cuk DC to DC Switching Converter, developed by CalTech Professors Slobodan Cuk and R.D. Middlebrook. The converter changes unsuitable dc voltage into one or more voltages suitable for powering electronic equipment; it can also be used in converting dc current to ac and vice versa. Named one of the 100 most significant technical advances of 1979, the Cuk converter is expected to find wide applicability in a great range of electrically-powered systems because it is more efficient than previous conversion devices, simpler, smaller, lighter, cheaper and highly reliable.

The first application of the technology is in the Compucorp 685 word data processor pictured at left; the processor is manufactured by Compucorp, Santa Monica, California. The converter, or switcher, is shown above.

NASA waived title rights to the technology to CalTech. CalTech granted an exclusive license to the inventors, Drs. Cuk and Middlebrook, who, in turn, transferred their rights to a company they founded called TESLAco, Pasadena, California. TESLAco sublicenses the converter design and related technology to companies making power supplies for use in their own products.

Automatic Welding System

Industrial firms have long been interested in robotic welding, which potentially offers higher productivity at lower cost than manual welding. A roadblock to broad commercial use has been lack of an effective guidance system—a means of guiding an arc welding torch along a seam without human intervention. There are some systems with automated arc guidance available, but they have disadvantages, such as limitations on types of materials or types of seams that can be welded; susceptibility to stray electrical signals; restricted field of view; or a tendency to contaminate the weld seam. Seeking to overcome these disadvantages and provide an effective system for automatic welding of space vehicle components, Marshall Space Flight Center, with the help of Hayes International Corporation, Huntsville, Alabama, developed a system that employs closed-circuit TV signals for automatic guidance of the welding torch.



NASA granted a license for commercial application of the technology to Combined Technologies, Inc. (CTI), Nashville, Tennessee, which developed a refined and improved arc guidance system based on the NASA work. CTI, in turn, licensed The Merrick Corporation, also of Nashville, for marketing and manufacturing of the new system, which is called the CT^2 Optical Tracker. The first purchaser of the device is Thompson Pipe & Steel Company, Denver, Colorado.

At upper right, a Thompson Pipe and Steel employee operating the manual seam tracker the company normally uses for welding large pipes, such as the 43½-inch-diameter pipe shown at right. The center photo shows a demonstration of the completely automated CT^2, whose principal elements are the TV camera and a microprocessor. The video unit views the area to be welded immediately ahead of the weld torch, and the pre-programmed computer automatically corrects the position of the torch if it is not precisely aligned with the weld joint. The CT^2 is a "non-contacting" system, meaning that its sensor follows a weld joint without touching its surface; this offers adaptability to a broader range of welding jobs and provides greater reliability in high speed operatons. The CT^2 can be used with any weld process, it is extremely accurate, and it can travel at a high speed—up to 150 inches per minute.

Power Controller

In alternating current (ac) induction motors, a substantial percentage of the power consumed may be wasted. The wastage is caused by the fact that power companies supply a fixed voltage to electric motors, based on what the motors need to handle the heaviest loads they are designed to carry. But the ac motor does not normally operate under full-load conditions, so a good part of the time it does not need the voltage supplied. Even when it is idling, it is still getting the fixed voltage; this creates high current flow and resulting heat loss just as if the motor were working hard.

A device to curb this wastage was developed by Marshall Space Flight Center (MSFC) engineer Frank Nola in the course of NASA's Solar Heating and Cooling Program, managed by MSFC. Called the Power Factor Controller (PFC), the device offers exceptional energy conservation potential by virtue of its ability to sense shifts in the relationship between voltage and current flow and to match them with the motor's need. When the PFC senses a light load, it cuts the voltage level to the minimum needed, which in turn reduces current flow and heat loss. Laboratory tests showed that the PFC could reduce power used by six to eight percent under normal motor loads and as much as 65 percent when the motor was idling.

More than 150 companies have sought and have been granted NASA licenses for commercial use of the PFC technology; some 30 companies are actively producing modified versions of the PFC. The accompanying photos illustrate one such system, the Vectrol Energy Saver (VES), produced by Vectrol Inc., Oldsmar, Florida, a subsidiary of Westinghouse Electric Corporation. The VES is produced in a series of models for electric motors ranging in capacity from five to 700 horsepower. In the photo at left is a VES used to control escalators at a Woodward & Lothrop department store in Wheaton, Maryland (below right). Woodward & Lothrop, which operates 14 stores with about 70 escalators, is interested in the energy savings possible through matching voltage with escalator load, which varies widely during a day. Ordinarily, the escalators draw power for maximum load; with the VES installed, energy use is regulated according to how many people are on the escalator at any time. Woodward & Lothrop estimates that the energy savings for the Wheaton test installation are 30 to 40 percent.

An aid to municipal sewage control highlights a sampling of spinoffs in the fields of environmental management and public safety

Space-Derived Sewer Monitor

The project manager inspects a sewer prior to installation of a QuadraScan monitor, a spinoff system for long term measurement of sewer flow.

In many U.S. cities, sewage treatment plants are dumping raw sewage into lakes, rivers and streams because the facilities were not designed to handle as much sewer flow as they are getting. Conversely, many cities have multimillion dollar sewage plants capable of handling far more flow than the municipality generates, an unnecessary outlay of civic funds. These system-sizing errors are illustrative of wastewater management problems that plague city officials, problems that stem from a basic informational deficiency: accurate, reliable data on how much water flows through a sewer system over a long period of time is very difficult to obtain.

A major factor is the flow of "groundwater," rain absorbed by the ground which seeps into the sewer system through leaks and cracks in pipes and sewer walls. The amount of groundwater entering the sewer fluctuates considerably, not only with the amount of rainfall but also with the degree of pipe deterioration in the sewer. Thus, instantaneous "one-time" measurements of water depth at selected spots in a sewer system, a method often used as a basis for estimating flow quantity, can produce substantial errors in calculating long term sewer flows. So city officials are increasingly turning to "permanent," or long term sewer monitoring systems—which are more accurate but subject to other problems. One, called "sensor drift," is an error-causing change over time in an instrument's calibration. Another is the possibility of frequent malfunction due to the

A technician checks out the electronic circuitry of the QuadraScan sewer monitor. An individual monitor continually measures water depth at a particular location in a sewer; a number of monitors, each reporting its findings to a central computer, provides information important to city managers on overall sewer flow, flow in any section of the city, location and severity of leaks and warning of potential overload.

harsh sewer environment in which monitors operate.

An aerospace-spinoff sewer monitor offers solutions to some of the wastewater manager's most pressing problems. Called the QuadraScan® Longterm Flow Monitoring System, it was developed by American Digital Systems, Inc. (ADS), Huntsville, Alabama. Highly accurate, QuadraScan can provide precise system-wide flow information for properly sizing sewage treatment facilities. Its accuracy allows improved customer billing, based on actual flow rather than "guesstimates." It can identify trouble spots, such as leaks, and target these areas for corrective action. Most importantly, QuadraScan answers the problems of sensor drift and potential malfunction by employing the aerospace technique of "system redundancy"—using multiple systems for the same job to guard against failure in any one sensor.

QuadraScan is a second generation sewer monitor, a major advancement over an earlier temporary system—called IsoScan—invented by ADS founder Peter Petroff. An aerospace engineer of 15 years experience, Petroff worked for NASA at Marshall Space Flight Center as a spacecraft instrumentation designer and for other aerospace organizations as an electronics specialist. In designing his initial sewer flow measurement system, he applied electronic circuitry and data collection principles based on expertise acquired in Apollo and other NASA programs. QuadraScan borrows even more heavily from space technology. Its data acquisition and memory system derives from NASA satellites; the instrumentation is similar to that of NASA's Orbiting Astronomical Observatory; the ultrasonic flow sensors are close relatives of ultrasonic devices used to orient space thrusters; and the sensors are protected by closed-cell foam customarily employed as protective encapsulation for satellite equipment.

QuadraScan is a compression of Quadredundant Scanning and Analysis Network, the "quad" meaning that each sewer monitor has four separate ultrasonic sensors, thus insuring accuracy and reliability since the readings of an individual sensor are confirmed by the others; if one is obviously in error, the computer ignores it and takes a consensus of the other three.

Typically, a number of monitors—each composed of the four sensors and a minicomputer housed in a sealed aluminum cylinder—are distributed throughout a city sewer system. The monitors, called "bats" because they operate on sonar, are fixed to the ceilings of sewer pipes. The bat emits a sonar pulse which is reflected back to the monitor when it strikes the water in the sewer. Since the sonar signal travels at the speed of sound, the computer can determine the distance from monitor to water by measuring—in microseconds—the signal's round trip travel time and compensating for the in-pipe temperature, which affects the speed of sound. Next, the computer subtracts the sonar reading from the known diameter of the pipe—and the result is the depth of the water flowing through the pipe. Hundreds of measurements can be taken and averaged within a few seconds; readings are consistently accurate to within a twentieth of an inch.

Connected by its own telephone line, the monitor's memory bank reports its findings to a central computer, which regularly and automatically collects data from all the monitors in the system and processes it into the end product—the overall flow rate for the city's entire sewer network. Flow readings from one section of the city can be compared with readings upstream and downstream; flow data can be correlated to weather conditions or to locations of key industries and other large contributors to the sewer system. In addition to providing input for informed decisions as to sewage plant sizing and maintenance of the sewer system, QuadraScan offers another major advantage: it can alert city engineers of approaching overload conditions which new businesses or housing developments might place on existing sewers. This early warning capability enables effective planning for city growth and helps a city avoid the crippling economic impact of "moratoriums" bans on new sewer connections in effect in many cities today.

American Digital Systems is a spinoff success story. The company began as a garage operation in 1975, then doubled its sales in each of the next six years. Today it has offices in 10 U.S. and Canadian cities and has installed QuadraScan systems in almost 100 municipalities, including such major cities as Washington, Baltimore, St. Louis and Oakland.

An American Digital Systems crew prepares to install a QuadraScan monitor (shown in foreground) in the Washington, D.C. sewer system. Almost 100 cities have QuadraScan systems, which are providing both economic and management efficiency benefits.

® QuadraScan is a registered trademark of American Digital Systems, Inc.

Visibility Studies

The accompanying photos are near-identical views from the campus of the University of Utah in Salt Lake City—except for the visibility. In the upper photo, taken on a clear day, the mountain range in center background—60 miles distant—is distinctly visible. It is totally obscured in the hazy day photo, in which the most distant features discernible—the mountains at left—are only 15 miles away. Comparison photos like these are used in atmospheric visibility studies conducted by the Environmental Studies Laboratory of the University of Utah Research Institute. The studies are part of a broader research program which embraces investigations of the effects of air pollutants on vegetation; air quality in arid and semi-arid regions surrounding energy developments; and the amount, size and type of particulates in the atmosphere.

In its visibility studies, the laboratory uses a computer program supplied by NASA's Computer Software Management and Information Center (COSMIC)*, located at the University of Georgia (see page 66). Called RADTMO, for Radiative Transfer Models, the COSMIC program computes the characteristics of scattered radiation in the atmosphere, including ozone concentration and aerosol density at various altitudes. These calculations provide information used in determining sky color intensity for visibility modeling under different atmospheric conditions. Through use of RADTMO, which was developed by Goddard Space Flight Center, the laboratory was able to avoid the cost of developing a new computer program; no other software capable of providing the necessary calculations was commercially available.

* COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Electronic Nose

Arson kills more than 1,000 people a year in the United States, causes injuries to thousands more and costs the nation some $5 billion annually. Law enforcement agencies, firefighters and insurance companies are increasing their efforts to identify and prosecute arsonists. An essential first step is determining the cause of the fire. An aerospace spinoff product is proving helpful in post-fire detection of flammable liquid "accelerants"—such as gasoline, benzene and many other combustibles—used by arsonists to speed up fire spread. The device employs the same electronic circuitry as a signal conditioning system originally developed for Langley Research Center.

Shown in use at a fire scene is the Electronic Nose* vapor and gas detector manufactured by Grace Industries, Inc., Transfer, Pennsylvania. Capable of sensing the presence of accelerants several days after a fire, the device is powered by a rechargeable battery and is so simple to operate that users need no special training. The investigator holds the Electronic Nose about an inch from the suspect material. If an accelerant is present, the device will emit a beeping sound and trigger a flashing light; the faster the beep rate, the more volatile the accelerant. Extremely sensitive, the Electronic Nose can detect minute traces of accelerants, for example, a hydrocarbon gas concentration of less than 50 parts per million. The unit saves investigators time and expense by providing speedy detection of physical evidence for use in court.

The Electronic Nose is widely used by police and fire departments, insurance claims departments and federal state agencies. It is used in criminal justice courses at the University of Texas, Austin, Texas, and in arson seminars conducted by Dr. Richard W. Henderson (shown in photo) at Francis Marion College, Florence, South Carolina. The device is also useful in other applications, such as detecting hazardous fumes, locating gas spills that have seeped into sewer systems and detecting gas leaks in refineries and on oil drilling rigs; several major companies are using it for the latter purpose. Grace Industries is producing about 1,000 units a year and plans introduction this year of a line of business and residential security systems based on the same electronic circuitry.

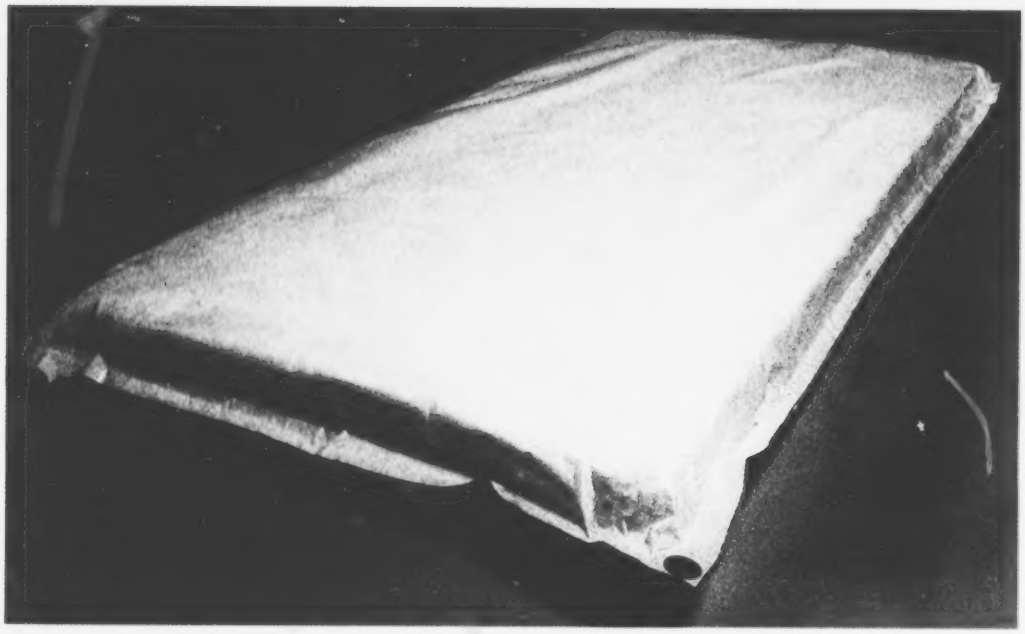
*Electronic Nose is a registered trademark of Grace Industries, Inc.

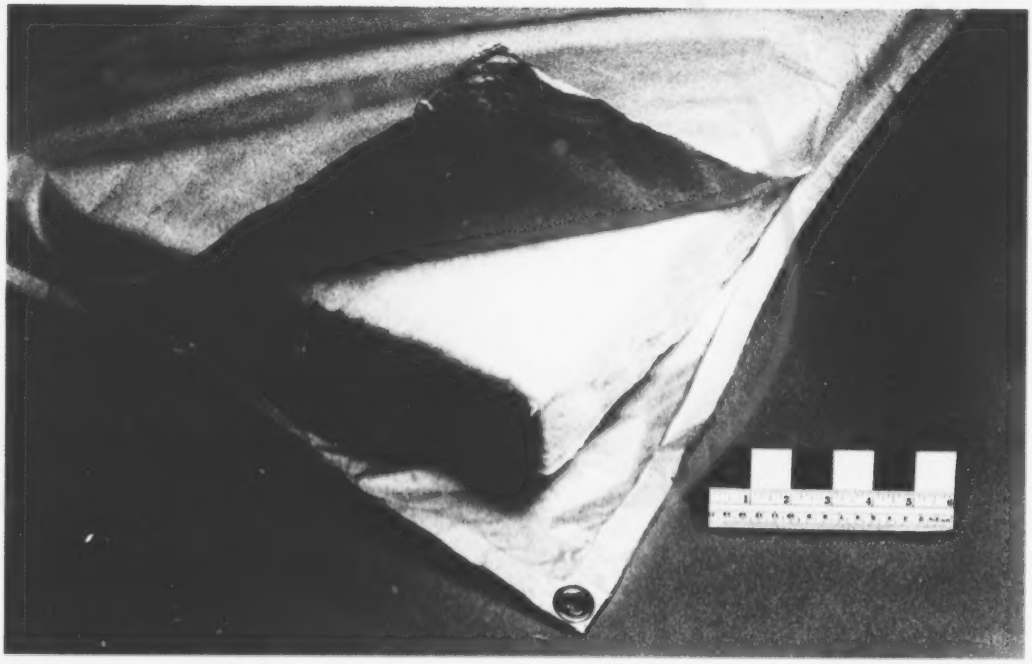
Poultry Plant Noise Control

The plant shown above and at left is Tip Top Poultry, Marietta, Georgia, site of a demonstration program of importance to the poultry processing industry. Conducted last winter, the demonstration was intended to show poultry plant managers from all over the U.S. potential solutions to a problem that has long frustrated the industry: plant noise.

In any industry, high noise levels pose many problems, such as low worker productivity, the risk of hearing damage, high worker turnover rates, and the possibility of fines for failure to comply with federal/state noise statutes. But the poultry industry has a special problem: in order to comply with U.S. Department of Agriculture sanitation regulations, all materials must be washable and must not present an opportunity for bacterial growth. These standards preclude the use of many conventional sound-absorbing materials. Some plants have experimented with specially-designed acoustic panels to absorb noise, but without success; the panels' plastic covers, needed to meet cleanability requirements, are not durable enough to withstand high-pressure water cleaning and other harsh maintenance procedures peculiar to the poultry processing industry.

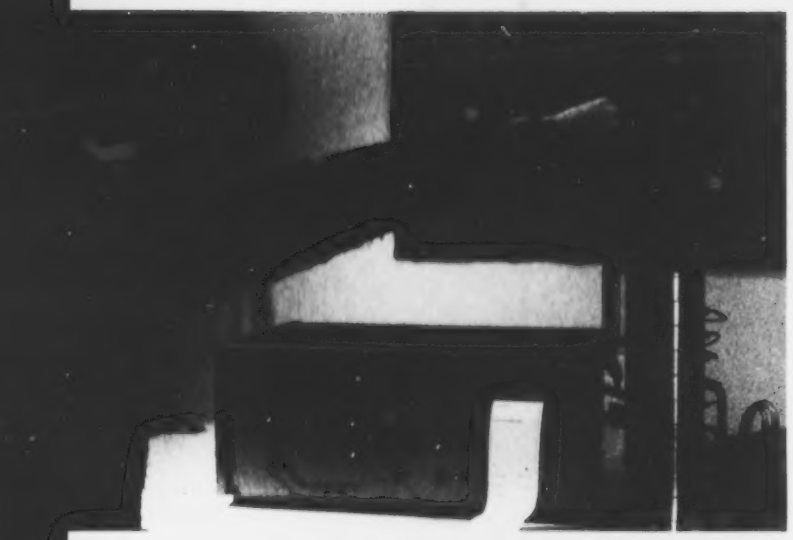
The Marietta demonstration marked the culmination of a three-year program in which Georgia Tech's Engineering Experiment Station (EES) studied the problem and identified potential solutions. The research was co-sponsored by NASA and the Georgia Department of Agriculture; Lewis Research Center provided sound

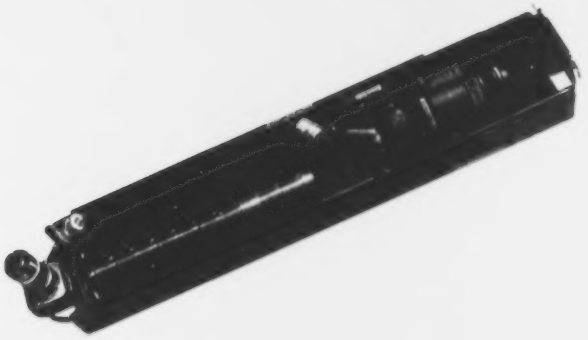




and vibration analysis expertise, together with information on aerospace materials which could be applied to reduce noise levels. The EES work included study of noise sources, how noise reverberates through a plant, and what measures might be taken to reduce noise levels. A major part of the research focused on designing a sound-absorbing panel with a cover which could be easily cleaned, was thin enough for desirable acoustic properties yet strong enough to resist puncture and tearing in cleaning and maintenance operations. After studying a variety of materials and designs, EES settled on a design (top) using a tough fiber-reinforced polyester film similar to that used in aerospace applications for vapor protection. The covering encloses a three-inch fiberglas core, shown above. The panels were suspended from ceilings at three-foot intervals to intercept and absorb noise.

For the full-scale demonstration at Tip Top Poultry, Fiber Flex, Inc., Newark, New Jersey manufactured and donated 750 noise panels; Owens-Corning Fiberglas Corporation, Toledo, Ohio donated the fiberglas cores; and the cover material was purchased from Howe and Bainbridge, Boston, Massachusetts. EES conducted before-and-after noise surveys and is evaluating the effect of noise reduction on turnover and productivity in the demonstration plant. EES plans to conduct a noise abatement workshop and update a handbook to help poultry processors deal with their individual noise problems. The results of the EES study and demonstration are considered applicable to other food processing applications where similar sanitary constraints exist.





Atmosphere Analyzer

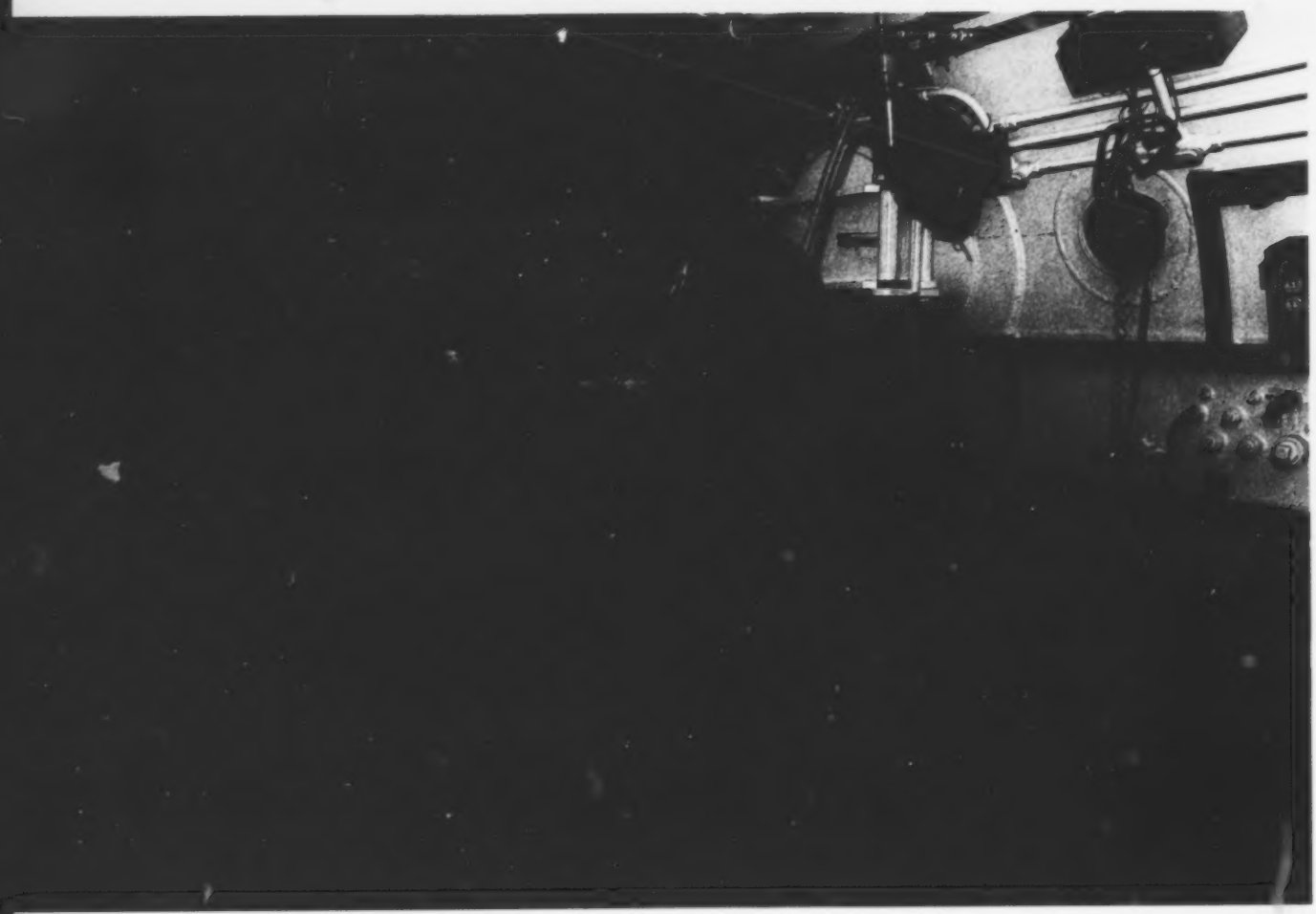
In air pollution studies, it is important to determine the quantities and sizes of aerosols in the atmosphere at a particular time. Aerosols are tiny solid particles or liquid droplets deposited in the atmosphere by natural events—such as volcanic eruption—or by human activities. Measuring them is very difficult because the ratios of the different contaminants are constantly changing. A NASA-developed technology—a quick and accurate method of detecting minute amounts of mass loadings on a quartz crystal—offers utility as a highly sensitive detector of fine particles suspended in air. When it is combined with a suitable air delivery system, it provides immediate information on the size distribution and mass concentrations of aerosols. The technology employs a dual-crystal sensor whose oscillating frequency changes in direct proportion to the amount of mass collected on the sensor. Electronic processing of the frequency changes provides mass collection information within seconds of a measurement.

Originally developed at Jet Propulsion Laboratory, the technology is incorporated in the device shown (above). Known as the Model PC-2 Aerosol Particle Analyzer, it is produced in both airborne and ground-use versions by California Measurements, Inc., Sierra Madre, California. The airborne PC-2 consists of a sensing pod (left) and an electronic control unit inside the airplane. The pod has 10 stages in tandem corresponding to particle sizes. Each stage is equipped with two sensing crystals and each has an inlet of decreasing size, so that the largest particles in an air sample are captured by the first stage and smaller particles flow to the next stage, until the system has sorted all particles into 10 size gradations. The crystal sensors report the particle concentration in each stage. The control unit provides a printout which

includes the time of the sampling period, the total mass concentration of aerosols and the concentration in each stage; an accompanying bar chart breaks down particle size distribution within the sample.

William Chiang, a former Jet Propulsion Laboratory engineer, founded California Measurements and obtained a NASA license for the multiple crystal oscillator technology. Initially, he developed—with Langley Research Center assistance—a particle analyzer for NASA use; later the company produced the modified PC-2 for commercial applications. Brunswick Corporation, Costa Mesa, California, uses the device for atmospheric research and in studies of smoke particles in fires. The PC-2 is used by pharmaceutical and chemical companies in research on inhalation toxicology and environmental health. It is also useful in testing various filters for safety masks and nuclear installations.

Among other examples of the system's utility, is an analyzer-equipped airplane, bottom left, flying into the smoke plume left by a launch vehicle blasting off from Kennedy Space Center; this is part of a Langley Research Center program for analyzing the effluents from solid rocket boosters. Along with other sensors, the device is flown routinely aboard Ames Research Center and Wallops Flight Center aircraft in studies of the effects of atmospheric aerosols on climate. Sampling volcanic effluents is another use of the device; at right is the Caribbean volcano La Soufrière on St. Vincent Island, which was sampled by a NASA-Wallops aircraft during a quiet period after an eruption. Below, the PC-2 is shown under the wing of a research airplane operated by the National Center for Atmospheric Research (NCAR), Boulder, Colorado; NCAR has used the device in several studies of aerosols and volcano effluents. Below right, a researcher is sampling within the crater of Mt. St. Helens, part of a 1981 U.S. Geological Survey test following the eruption of the preceding year.



Fire Resistant Materials

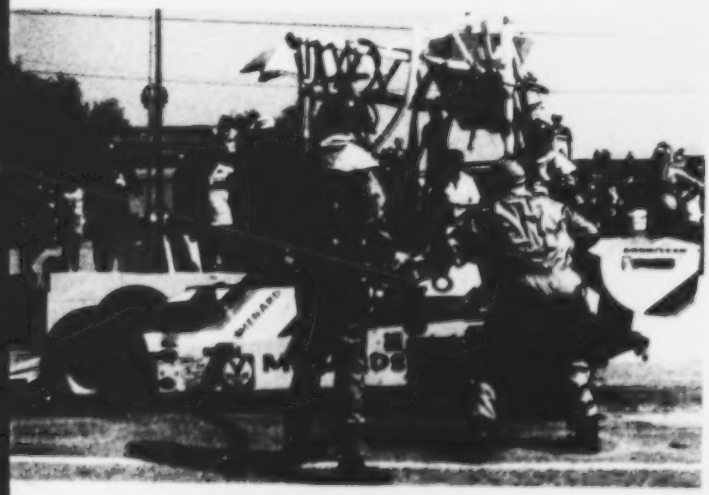
In atmospheres containing a high percentage of oxygen under pressure—such as a manned spacecraft—fire hazard is greater than normal. After a 1967 Apollo fire, NASA intensified its fire safety research and sought new fire-retarding materials for greater protection of astronauts in an oxygen-rich environment. Under contract with Johnson Space Center, several companies developed new and improved materials. Among them was a chemically-treated fabric called Durette® —developed by Monsanto Company, St. Louis, Missouri—which will not burn or produce noxious fumes, even in an oxygen-enriched atmosphere.

Durette was selected as a material for Apollo astronaut garments. Subsequently, Monsanto sold production rights for the material to Fire Safe Products (FSP), also of St. Louis. FSP is now producing Durette for a wide range of applications.

An example of a non-aerospace application is shown in the photo above, which pictures a hyperbaric chamber at the University of Pennsylvania Medical Center s Institute for Environmental Medicine, Philadelphia, Pennsylvania. Known for its research on deep diving and oxygen therapy, the Institute is one of several hyperbaric and undersea medical centers that use Durette fabrics for safety.

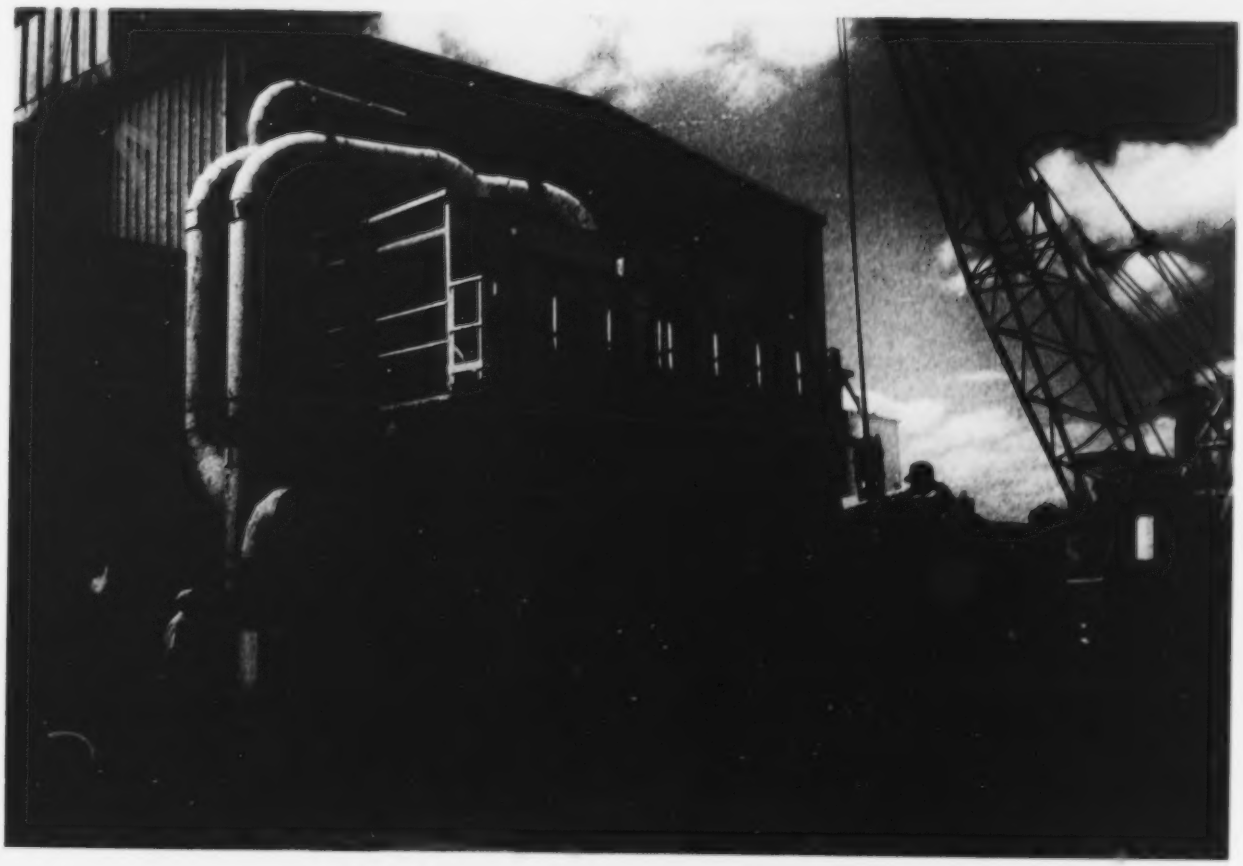
® Durette is a registered trademark of the Monsanto Company

Pressure chambers are employed for treatment of a number of conditions which respond favorably to oxygen at elevated pressures, including divers' decompression sickness, or "bends," chronically-infected non-healing bone fractures, carbon monoxide poisoning and gas gangrene. In the chamber, the patient breathes oxygen at about twice normal atmospheric pressure. The increased fire risk of the hyperbaric environment is offset by reducing the amount of combustible material in the chamber through use of Durette in sheets, patients' garb and attendants' uniforms. For similar reasons, Durette is used in crew clothing, furniture and interior walls of diving chambers operated by the U.S. Navy and a number of oceanographic companies and research organizations.



A different type of Durette usage is illustrated in the photo at left, taken at an auto raceway in Riverside, California. In auto racing, fire is a hazard not only in track accidents but also in pit-stop refueling operations; in the photo, the driver, refueler and crew chief are wearing Durette suits made by Pyrotect Safety Equipment, Minneapolis, Minnesota from material supplied by FSP.

FSP's most recent product is Durette bags for filtering gases and dust from smelters, boilers, electric generators and similar systems. Durette felt bags are part of the Kice Hi-Temp Filter connected to the "cupola" — a large coke-burning furnace—shown below. Produced by Kice Metal Products Company, Inc., Wichita, Kansas, the filter cleans cupola emissions by removing pollutant particles from the hot smoke. Kice Metal Products states that the Durette bags can operate at more than 500 degrees Fahrenheit and that the only other felted fiber capable of operating at that temperature costs twice as much.



Self-righting Life Raft

During 1980's Hurricane Allen, a 30-ton yacht plying the Caribbean between Jamaica and Cuba was literally lifted out of the water and capsized by winds estimated at more than 200 miles per hour. But the four men aboard survived in a unique, high-stability, inflatable life raft which rode out the fierce winds and enormous seas for 42 hours until the group was picked up by a Norwegian tanker.

Their survival craft was a Givens Buoy Life Raft, designed and manufactured for inventor Jim Givens of Tiverton, Rhode Island by RPR Industries, Inc., Apex, North Carolina. The raft, which consists of a canopied topside and an underwater hemispheric ballast chamber, is displayed by Givens and his wife Meredith (above). The Caribbean incident was one of many in which the 75-pound raft has demonstrated its ability to withstand extremely adverse weather conditions. It is credited with saving 230 lives in the last five years.

Many seagoing vessels use inflatable life rafts as primary survival equipment. The U.S. Coast Guard requires that American-built rafts have stabilizing devices—such as water bags or "pockets"—which provide limited ballast. But the Coast Guard has acknowledged that conventional lightly-ballasted rafts can be capsized by high winds or heavy seas, possibly drowning the occupants when the inside of the raft floods.

The Givens Buoy Life Raft has a heavy ballast stabilization system which negates the capsizing problem. A "flapper valve" admits large amounts of water to the hemisphere chamber, providing ballast to keep the center of gravity constant; the stabilization system compensates for changes in wave angle and for weight-shifting as raft occupants move about. The raft cannot overturn in normal seas; the photo below illustrates a test in which Coast Guard personnel tried to capsize the raft but could not. If a rogue wave of

exceptional strength should overturn the raft, it will somersault and right itself, as it has done repeatedly in actual survival operations.

The Givens raft is based in part on NASA technology. During the Apollo program, ocean-landed astronauts left their Command Modules and waited in inflatable rafts for pickup by helicopter. NASA found that improperly-ballasted flat bottom rafts tended to overturn under the force of the helicopter's downwash. So Johnson Space Center developed a new method of raft stabilization for which NASA secured a patent. Working independently, Jim Givens developed a very similar system. He patented his own invention and obtained an exclusive patent license for use of the NASA technology.

Produced in various sizes, the Givens Buoy Life Raft has capacities ranging from six to 20 persons. The raft is housed in a canister, available in several configurations for compact stowage aboard different types of vessels; two box-like canisters are shown above and two "low profile" versions for yachts are pictured at right. A pull on a line triggers the automatic inflation process. Inflation snaps the canister's bands, the dual buoyancy chambers inflate and the self-erecting canopy covers the raft's topside. The whole process takes 12 seconds.

The Givens raft has found wide acceptance among operators of fishing boats, pleasure craft and other vessels; some 6,000 rafts are in worldwide use. The Coast Guard is purchasing Givens rafts for use on its rescue helicopters and the Navy has a development program to adapt the system. Last year, the Coast Guard announced a proposed amendment to its regulations that would require large ballast chambers on all inflatable life rafts.

Spurred by NASA technological advances, a budding industry is manufacturing equipment and providing services toward better management of Earth's resources

The Earthscan Industry

Remote sensing is the acquisition of physical information from a source some distance away. It is as old as man, for the human eye is a remote sensor. When primitive man scaled a mountain for a better look at the valley, he was sensing from a distance. So was Galileo when, in 1610, he turned his newly-developed telescope toward the moon. Perhaps the first effort to utilize remote sensing as a practical Earth-survey tool came in the middle of the 19th century when aerial photos of Paris were made from a balloon.

Since 1959, when the first picture of Earth was taken from a satellite, a remote sensing has progressed to sophisticated science that offers high potential for public benefit, particularly in better management of Earth's resources. By itself, remote sensing is not a total information system, nor does it replace traditional means of gathering resources data; it is an additional tool capable of providing voluminuous information not readily collectible by other means. When incorporated into a larger information system that utilizes data from various other sources, the technology offers broad utility in such areas as agricultural inventory, prospecting for new oil and mineral resources, charting sources of fresh water, monitoring air and water pollution, delineating urban growth patterns, studying floods to lessen their devastation, improving the accuracy of maps, plotting ecological changes resulting from earthquakes, forest fires or strip mining activities, and scores of other applications.

There are many different systems for acquiring Earth information from airborne or orbiting platforms, for example, advanced photographic systems, imaging radars, infrared devices, laser detectors and multispectral scanners (MSS). A description of the latter system, as it is employed aboard NASA's Landsat survey satellites, best exemplifies the remote sensing process.

The MSS is designed to take advantage of the fact that every object on Earth reflects light or emits radiation in different wavelengths of the electromagnetic spectrum. Thus, each object has its own unique radiation "signature" which, like a human fingerprint, offers a means of identifying a particular object. As Landsat orbits Earth, the sensitive detectors of the MSS pick up these signatures, including radiations in both visible light and in parts of the spectrum not visible to the human eye. Converted to digital signals, the information is transmitted to a ground station where a computerized signal-deciphering system translates the flow of data into tapes and images—electronic pictures of Earth. Landsat data can be interpreted to tell the difference, for example, between one type of vegetation and another, between densely populated urban areas and lightly populated farmland, or between clear and polluted water. The basic imagery can be enhanced by computer processing to correct sensor errors, to compensate for atmospheric effects or changing Sun angle, to make the image compatible with standard maps, or to emphasize certain features in the image.

Toward exploiting the remote sensing potential, NASA has led the way in developing satellites, sensors and other on-board equipment, along with means of processing the data acquired by satellites or aircraft. So far, the major users of remotely-sensed data have been federal, state and local governments, but the private sector has become more aware of the technology and its possibilities for economic and productivity gain. Resource exploration companies looking for oil, gas and mineral sources are the

largest private sector users and the technology is beginning to find acceptance in other industries.

To support both government and private users, there is a small but growing commercial remote sensing industry. It cannot yet be described as a "booming" industry, but there is real promise for expansion. The industry consists of about 150 firms, some of them long engaged in aerial photography and now moving into other sensing activities; others are relative newcomers to the field, companies which have been formed in the last decade or so to pursue the opportunities afforded by satellite remote sensing. Some of these firms manufacture various types of sensors used in aircraft or spacecraft; others produce ground-use equipment for computer-processing the data acquired; still others offer a variety of specialized services ranging from aerial photography to interpretation and analysis of data.

An example of a company engaged in all these areas is General Electric's Space Systems Division, Valley Forge, Pennsylvania, which builds the Landsat satellites, manufactures equipment for ground processing of data, and offers Landsat image analysis services to a variety of users. The most recent of these offerings, provided by GE's Earth Resources Applications, Lanham, Maryland, is a Landsat geologic reconnaissance package—called GEOPAK *—that enables exploration geologists to evaluate quickly large areas of Earth for resource potential.

GE's customers get a Landsat image of a specified area, geometrically corrected to make it map-compatible, and computer-enhanced to emphasize topographic features and subtle color differences. The package also

On the opposite page, a General Electric technician is using a computerized image analyzer to process a Landsat image, a first step in preparation of the company's GEOPAK information package designed to aid companies prospecting for oil or natural gas. At left is an example of the basic GEOPAK package, an image of a part of Utah which has been coordinated with standard maps and computer-enhanced to emphasize topographic and subtle color features. Below, a GE geologist is adding an overlay to the image; the overlay is part of a geologic analysis which pinpoints Earth faults, fractures, domes and other features of interest to prospectors.

includes a geologic analysis which pinpoints lineaments—such as faults and fractures—along with surface structural features and other indicators of prospecting potential. The GEOPAK package is not an instant oil discovery system, GE officials state; it is simply another tool, useful in the early stages of geologic exploration as an aid to focusing on most promising areas. Its advantage is that it provides geologists a packaged analysis in six weeks that would otherwise require months and many miles of surface examinations to accomplish. The GEOPAK program was introduced in 1980 and since then the volume of business has grown consistently.

Some other examples of commercial remote sensing companies, the types of equipment they produce and the services they provide are contained in the following pages.

* GEOPAK is a trademark of General Electric Company

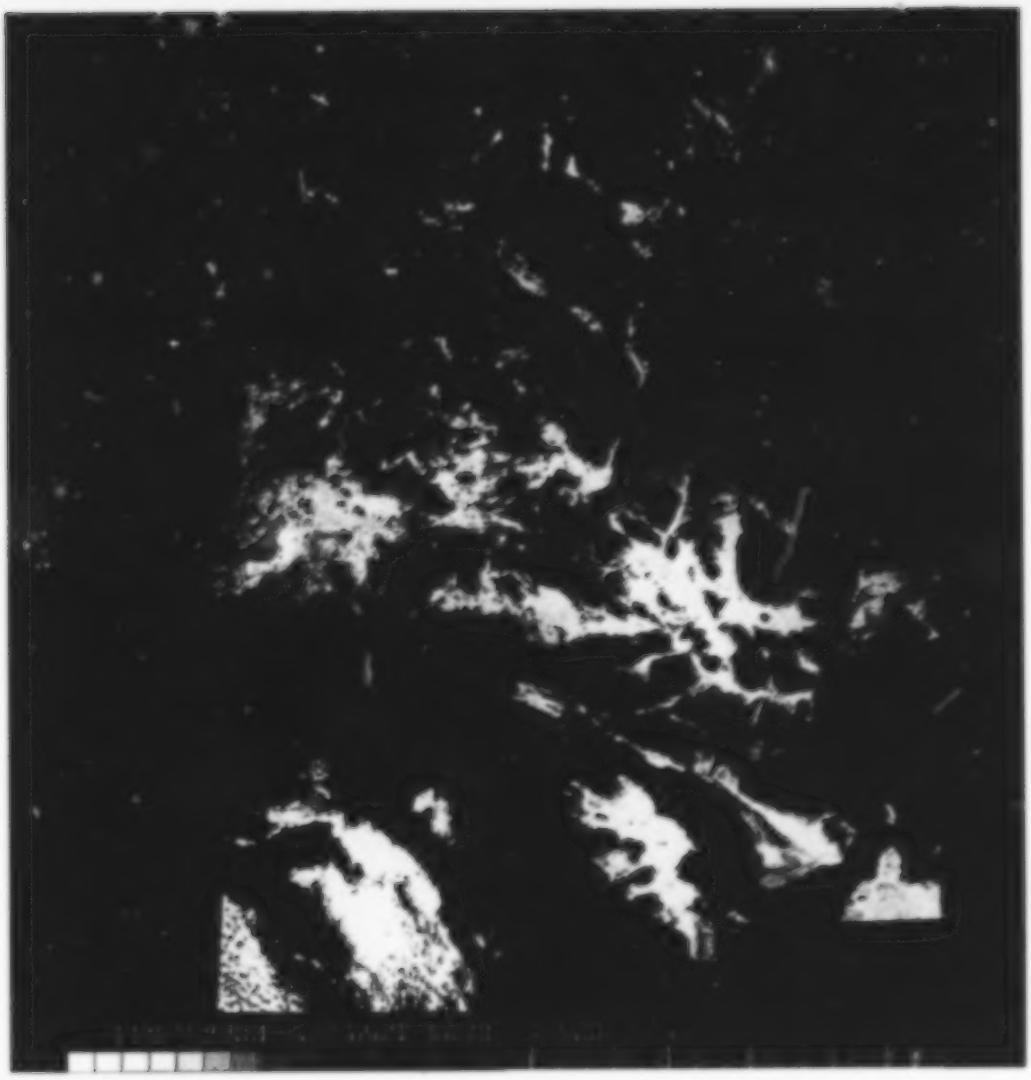


Image Processing

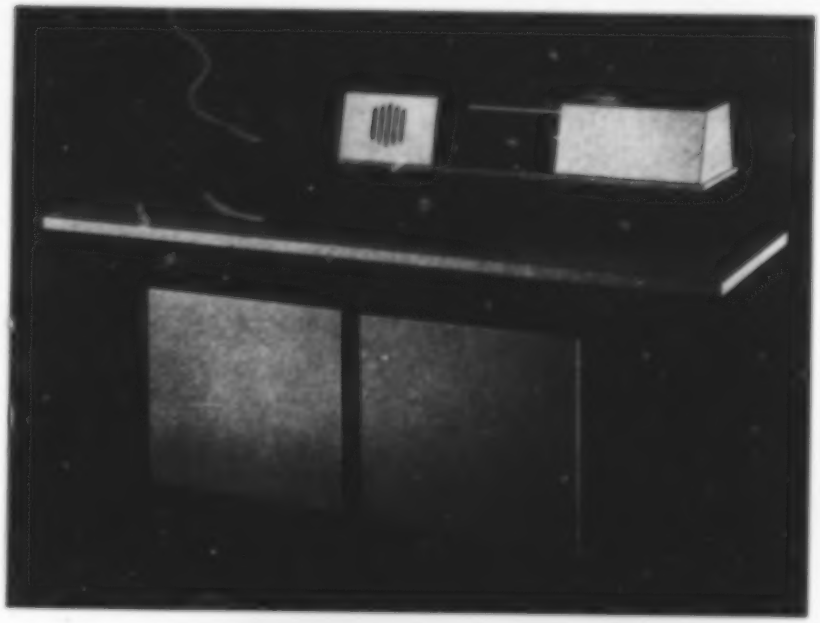
The image above is a mosaic composed of 12 scenes acquired by a Landsat Earth survey satellite. It covers the southern third of California and parts of Arizona, Nevada, Utah and Mexico; an analyst can readily identify such features as the Grand Canyon, Lake Mead and the San Andreas Fault. This image underlines one of the major advantages of Landsat technology in Earth resources management: the ability to show analysts surface features over a very large area. It is also an example of how appropriate computer processing can supply highly informative detail of Earth's surface, including objects not visible to the human eye or to conventional cameras. each of the image's computer-assigned colors represents a different feature, such as urban land, water, vegetation, rock or desert.

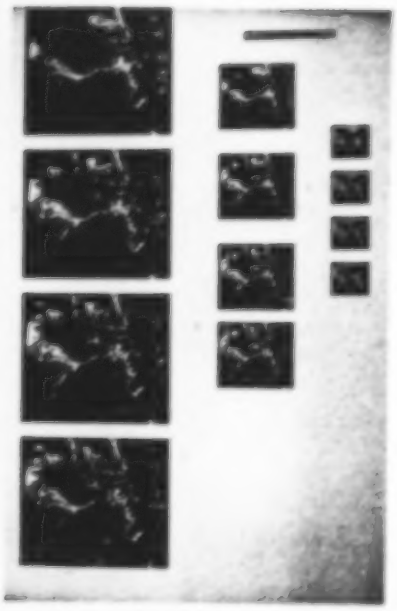
Images like this are prepared from data acquired by the multispectral scanner aboard Landsat, which views Earth in four ranges of the electromagnetic spectrum: two visible bands and two in infrared. The scanner picks up radiations from ground objects and converts the radiation signatures to digital signals, which are relayed to Earth and recorded on tape. A typical satellite image contains about 10 million pixels, or picture elements.

each covering a ground area 1.5 meters square. computerized equipment processes the tapes and plots each pixel, line by line, to produce the basic image. The image can be further processed to correct sensor errors, to heighten contrast for feature emphasis, or to enhance the end product in other ways. The key factor in conversion of digital data to visual form is the precision of the processing equipment.

The mosaic shown contains roughly 165 million pixels in three bands of the spectrum. It was prepared from tapes by Jet Propulsion Laboratory, then plotted and enhanced by Optronics International, Inc., Chelmsford, Massachusetts by means of the company's C-4300 Colorwrite, a high precision, high speed system which manipulates and analyzes digital data and presents it in visual form on film.

A large area image like the one shown offers a new perspective for resource study and also serves as a frame of reference for more detailed studies of smaller selected areas to identify such factors as water depth or geological patterns. Enhanced imagery is useful to geologists, hydrologists, land use planners, agricultural specialists and geographers, to mention only a few, but each has a different level of interest in relief, boundary definition, color contrast and the spectral range of the imagery. To meet all users' needs, Optronics manufactures a complete family of processing systems, two of which are pictured. In center page is the C-4500 Colormation, an advanced scanner plotter film recorder; at lower left is the Model L-5500 Laserwriter, a high resolution image recorder; at right below are samples of the L-5500's work, four bands of a typical Landsat image recorded at different degrees of detail clarity. The world leader in manufacture of digital image processing hardware for the remote sensing community, Optronics has supplied systems for some 500 users in 40 countries.





Multispectral Photography

Shown below is an advanced aerial camera capable of detecting subtle differences in Earth conditions not detectable by conventional aerial photography. Called the Model 11 Multispectral Camera, it was developed by Spectral Data Corporation, Hauppage, New York. The camera provides optimum enhancement of a scene by recording spectral signatures of ground objects only in narrow, preselected bands of the electromagnetic spectrum. Its photos have application in such areas as agriculture, forestry, water pollution investigations, soil analysis, geologic exploration, water depth studies and camouflage detection.

Before an aerial survey begins, technicians first determine the spectral characteristics that distinguish the target object or condition. For example, a certain species of plant life exhibits a different signature from its surrounding environment because of its unique physiological properties. The difference is measured and plotted, enabling selection of the "information bands" of the spectrum which best contrast the target's signature with its background. Each of the camera's four lenses is fitted with a special filter and the lens filter combinations are adjusted according to the target's spectral properties. The target scene is then simultaneously photographed in four separate spectral bands.

In the next step, Spectral Data employs a multispectral viewer—such as the company s Model 75 (opposite page below)—to create a color image from the black-and-white positives taken by the camera. With this optical image analysis unit, all four bands are superimposed in accurate registration and illuminated with combinations of blue, green, red and white light. The best color combination for displaying the target object is selected and printed.

An example of the end product is shown at right, an image made during a forest management study of how effective remote sensing systems can be in early detection of tree stress caused by Dutch elm disease. In the image, the reddish-brown trees are healthy; green trees are diseased but the damage cannot yet be detected visually; the blue trees show visually detectable signs of the disease. The Spectral Data system showed the best visual discrimination between healthy and diseased trees. In many cases, the imagery revealed indications of stress before it was visible to ground surveyors; further comparisons showed that multispectral photography could also be employed as a predictive tool.

Another example is an image (below) of an agricultural area which included opium poppy fields. Remote sensing of poppy growth is extremely useful in enforcing narcotics laws and controlling drug traffic. Spectral Data has successfully employed multispectral photography for this purpose internationally. This image shows a variety of crops in different colors: the gold or beige tones indicate opium poppy fields. In center photo (arrow) is an illicit poppy field (gold) which was cultivated in the middle of a rye field (red) for camouflage purposes at ground level.

Spectral Data produces several types of remote sensing equipment, including systems for plotting, interpreting and viewing data from aerial surveys or from Landsat satellites. The company also provides aerial survey, image processing and analysis, and a number of other remote sensing services.

Ground Use Sensor

Along with airborne and spaceborne instruments, remote sensing techniques employ a number of ground use sensory systems for measuring and analyzing radiation reflected from Earth targets to discriminate among classes of visually-similar objects. One use of such systems is "ground truthing," making on-the-spot examinations of ground targets as a means of verifying satellite data. Ground use systems can also be employed independently in a wide range of applications.

An example of a ground use device is the system shown in the accompanying photo. Called the Hand Held Ratioing Radiometer, it was developed by Jet Propulsion Laboratory in the course of NASA-sponsored research. It is now being manufactured and sold by Barringer Research Limited, Rexdale, Ontario under a patent license. Designed for field portable use, the battery-powered unit weighs only 12 pounds.

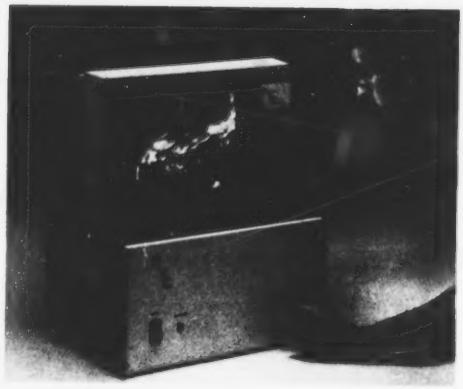
A radiometer is an instrument for measuring the intensity of reflected radiation. The Barringer Ratioing Radiometer has an added capability: it simultaneously analyzes radiation intensities in two separate bands of the spectrum and calculates the ratio of one to the other; this affords more positive identification of the material being analyzed. The "reflectance ratio" is displayed in digital form; this information enables analysts to determine the particular characteristics of the target.

One application, illustrated in the photo, is examination of rock for the presence of specific minerals; in addition to its analytical capability, the system offers extra field prospecting utility by providing instant results on-site, eliminating the necessity for laboratory analysis of samples. Another use is determining the health status and yield potential of agricultural crops. Among many other applications are studies of water quality, water color as an indication of sediment, algae growth, soil moisture content and other soil characteristics, and pollution effect on forest cover.

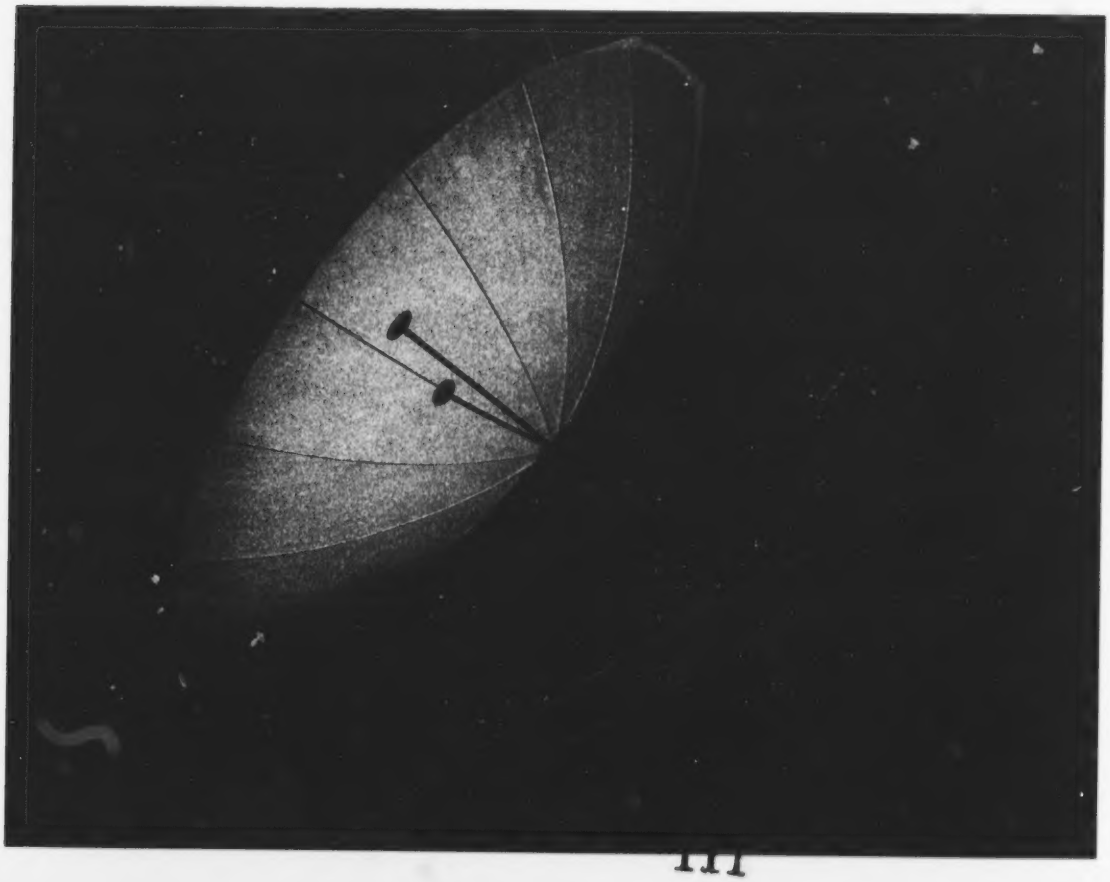
Weather Data Receiver

Included in the family of remote sensing satellites are those which report weather and other environmental information. For the most part, these satellites beam their signals to Earth stations equipped with large antennas and elaborate data processing equipment. The resulting weather pictures are relayed via commercial telephone land lines to users, who need their own processing systems. Because of the expensive equipment required, maintenance costs and phone line charges, satellite data reception is largely limited to government agencies, meterorological organizations and large television stations or networks. To make weather pictures available to a broader user community, Northern Video Graphics, Inc., Minneapolis, Minnesota has developed a low-cost satellite receiving system intended for such users as independent meteorologists, agribusiness firms, small airports or flying clubs, marine vessels and small TV stations. Called Video Fax, the system is based in part on NASA technology.

Video Fax is designed for use with certain satellites, such as the GOES (Geostationary Operational Environmental Satellite) spacecraft operated by the National Oceanic and Atmospheric Administration, the European Space Agency's Meteosat and Japan's Geostationary Meteorological Satellite. By dictum of the World Meteorological Organization, signals from satellites are available to anyone without cost. Thus, the Video Fax user can acquire signals directly from the satellite and cut out the middle man, enabling savings in telephone charges and other processing costs. The unit sells for about one-fifth the cost of the equipment used by TV stations.



Video Fax consists of a two-meter diameter antenna (below) whose design is based on technology developed by Goddard Space Flight Center; a receiver; a microprocessor-controlled display computer; and a video monitor (above). The computer stores data from the satellites and converts it to an image which is displayed on the monitor. The weather map can be preserved as signal data on tape or it can be stored in a video cassette as a permanent image.



New Technology for Fire Attire

A project for improving firefighting gear typifies NASA demonstrations of technology designed to provide better ways of meeting public needs

Firefighting is the most hazardous public service occupation in the United States. Little can be done about reducing the risks to which firefighters are exposed; risk is the nature of the job. But something can be done to curb firefighting injuries and fatalities. That's the goal of Project FIRES, a program jointly sponsored by NASA and the Federal Emergency Management Agency's U.S. Fire Administration (USFA).

FIRES is an acronym for Firefighters' Integrated Response Equipment System, which describes the program's objective: improving the firefighter's "envelope," including the major elements of protective clothing and equipment. After five years of study and development, Project FIRES reached a milestone this year when a number of U.S. fire departments began field evaluation of an advanced technology ensemble—suit, helmet, boots and gloves—that could become the standard firefighting attire of the future.

Project FIRES involves application of advanced materials and design concepts to update protective gear which had gone basically unchanged for half a century. Existing "turnouts," as firefighters call their gear, do not adequately protect against many of the hazards encountered in fire suppression activities. They may, in fact, contribute to exhaustion because they are heavy and restrict mobility.

The program represents a systematic approach to developing ensembles which offer maximum protection and greater ease of movement at significantly reduced weight and at a cost which fire departments can afford to pay. Technical management for Project FIRES was provided by Marshall Space Flight Center, working with a User Requirements Committee whose membership included various segments of the firefighting community. Prime contractor for the project is Grumman Advanced Development Division, Bethpage, New York.

A major focus of the effort involves application to the FIRES ensemble of lightweight, fire-resistant,

Members of the Alexandria (Virginia) Fire Department show off their new firefighting gear, developed in a joint NASA/U.S. Fire Administration program to improve fire suppression equipment and reduce fireground injuries. At left, the yellow and green suits are slightly different in design and are made of different types of lightweight, fire-resistant materials. At upper right, one firefighter is donning the "short-jacket" ensemble. Far right, the long-jacket version is modeled against the backdrop of a 19th century steam pump. The Alexandria unit is one of 14 U.S. fire departments participating in a nine-month nationwide evaluation of the gear.

heat-protective materials originally developed for use in astronauts' space suits or in spacecraft components which require thermal protection. An example is a material called polybenzimidazole, or PBI©, produced by Celanese® Corporation, New York. In the aftermath of the tragic Apollo fire of 1967, Celanese began development of PBI—in conjunction with NASA and the Air Force Materials Laboratory—as a flight suit material which would afford pilots and astronauts maximum protection from fire; it was subsequently used on Apollo flights. PBI fabric does not burn or melt at temperatures encountered in structural fires, it has high abrasion resistance and, in addition, it offers flexibility and wearer comfort. Materials with similar characteristics being evaluated in FIRES are blends of Nomex® and Kevlar®, produced by DuPont Company, Wilmington, Delaware. The FIRES ensemble weighs only about 12½ pounds—40 percent less than current equipment.

Another area of focus is the "vapor barrier," a middle lining between the exterior fire-resistant material and the inner thermal lining. The vapor barrier is designed to maintain thermal protection by keeping the thermal liner dry. The barrier must protect against heat while keeping the body dry; it must also allow the body to "breathe." This feature protects against excessive heat stress, which causes almost half of all firefighter fatalities experienced annually. The Project FIRES turnout accomplishes this by using a lightweight barrier material called GORE-TEX® film—produced by W. L. Gore & Associates, Elkton, Maryland—that contains some nine billion pores per square inch. The GORE-TEX barrier keeps the turnout gear absolutely waterproof while allowing moisture vapor and body heat to dissipate outward through the tiny pores. This is possible because each pore is 700 times larger than a molecule of water vapor but 20,000 times smaller than a drop of water.

Similar careful attention was given to the design and selection of materials for other elements of the ensemble—boots, gloves, helmet and face shield. Marshall Space Flight Center required that all of this equipment be thoroughly tested for heat, impact, cut and penetration resistance before it was released for field evaluation.

Fourteen municipal fire departments are participating in the field evaluation, which will continue through 1983. The municipalities, located from coast to coast and from the northern to southern borders of the U.S., offer a representative cross-section of American firefighting experience as regards geographical location, climate, frequency of alarms and varied usage of equipment. Data from the evaluation will form a basis for development of new nationwide protective ensemble standards.

Project FIRES exemplifies a special area of NASA's Technology Utilization Program: demonstrations to show how application of advanced technology may help solve major problems or provide better ways of meeting public needs. Some product spinoff may evolve from such demonstrations, but product commercialization is not the primary aim; the intent is to create awareness of the advantageous technology and to inspire its broader application. The following pages contain other examples of NASA's participation in similar programs.

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Shock Absorbing System

Sometimes an aerospace-developed system with clear spinoff potential languishes on the shelf for lack of an immediate application, then is rediscovered years later as advancing technology in other areas creates a need. An example is a lightweight, inexpensive shock-absorbing system developed by Langley Research Center two decades ago, now in service as a safety device for an automated railway at Duke University Medical Center, Durham, North Carolina (below).

In the early days of space flight, NASA was looking for a means of dissipating the energy generated by a spacecraft landing at excess velocity on Earth, the moon or another planet. Langley's answer was a "frangible"—breakable—metal tube incorporated in the spacecraft's landing leg. If the spacecraft were to hit the surface at a descent rate greater than intended, the impact would shatter the tube; in the process of fragmenting, the tube would absorb energy and reduce the landing shock.

The Transportation Technology Division of Otis Elevator Company, Denver, Colorado found a use for the innovation in the design of Duke's People Cargo Transportation System. The need for the "people mover" arose when the Medical Center expanded its facilities to include, in addition to the existing hospital, a second

hospital a quarter of a mile distant. The transportation system consists of four electrically-propelled 22-passenger vehicles, like those shown above, which move on a cushion of air along guideways connecting the two hospitals and a parking lot. Carrying patients, visitors, staff and cargo at about 25 miles per hour, the cars stop automatically at terminals in each hospital and in the parking area. At the ends of each guideway are frangible tube "buffers" (right). If a slowing car should fail to make a complete stop at the terminal, it would bump and shatter the tubes, absorbing energy that might otherwise jolt the passengers or damage the vehicle.

Otis Elevator learned of this technology several years ago when, under a NASA grant, Denver Research Institute (DRI) was testing the potential of frangible tubing for such civil applications as elevator or auto bumper shock absorbers. Otis conducted the elevator tests under subcontract with DRI. This experience led to the company's incorporation of the tubular energy absorbers in the Duke system, in lieu of a more complicated and expensive hydraulic device.

Agricultural Aircraft Aid

Farmers are increasingly turning to aerial application of pesticides, fertilizers and other materials, due to growing costs of doing these jobs by ground methods. Sometimes, however, the advantages of aerial crop spraying are negated by uneven distribution of the chemicals, caused by such factors as improper alignment of spray nozzles, worn nozzles or system leaks. When that happens, the job must be redone, with added expense for both pilot and customer. In most cases, the applicator could readily correct the problem if he could accurately measure the deposition of the chemicals to find out why the dispersal pattern was not uniform. But traditional pattern analysis techniques may take days or even weeks; to operate effectively, pilots need a quicker way of getting the information.

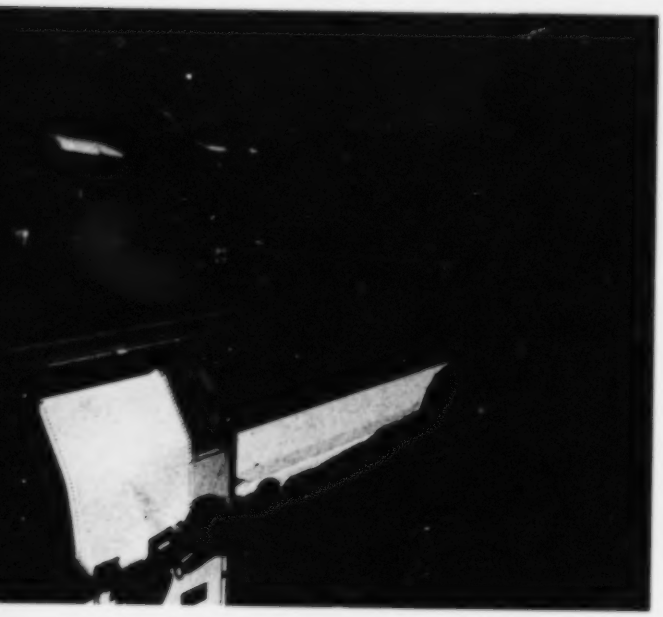
Dr. Lawrence O. Roth, Professor of Agricultural Engineering at Oklahoma State University (OSU), has developed a system for providing answers within minutes. He was assisted in his work by a NASA funding grant, by wind tunnel and computer validation of his research and by the technical expertise of Langley Research Center and Wallops Flight Center, which are extensively engaged in technology development for agricultural aircraft.

Called the Rapid Distribution Pattern Evaluation System, the OSU system consists of a 100-foot measurement frame tied in to computerized analysis and readout equipment. The frame is placed perpendicular to the flight path of a spray plane (top) to collect samples of either liquid or granular materials. To test liquid deposition patterns, the sprayplane's tanks are loaded with a fluorescent dye. As the plane passes overhead, droplets of the dye fall onto a paper tape running the length of the frame; at left, a researcher is examining a tape. The tape is then fed into a scanning instrument called a "fluorometer" which analyzes the quantities of droplets along the length of the tape. A computer

readout (below) provides a chart of the "peaks and valleys" in the distribution pattern.

For granular material, the procedure is somewhat different. Across the frame are a series of one meter square bins which collect particles during a test pass. The particles are weighed to determine the amount of material that fell in each area; the data is entered into the computer, which produces a pattern chart.

The OSU system is mobile, delivered by trailer to airfields in agricultural areas where OSU conducts educational "fly-ins." A fly-in typically draws 50–150 aerial applicators, researchers, chemical suppliers and regulatory officials. An applicator can have his spray pattern checked—usually by flying three passes over the measuring system. A computerized readout, available in five to 12 minutes, provides information for correcting shortcomings in the distribution pattern, for example, nozzle repairs, additional nozzles or just rearrangement



of nozzles. In the latter case, the applicator can make on-the-spot adjustments (right) and recheck his pattern. Other users of the OSU system include agricultural aircraft manufacturers seeking to develop or improve dispersal systems for their aircraft.

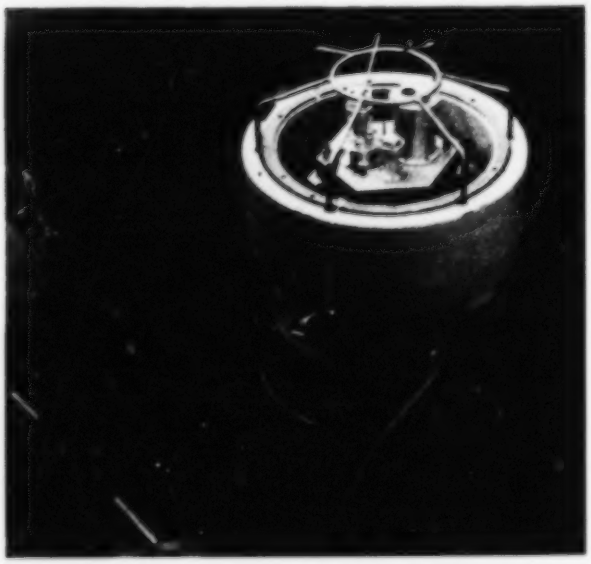
This year, a commercial version of the OSU system will form the backbone of Operation SAFE, an industry-sponsored program, being implemented by the National Agricultural Aviation Association, to improve the safety and efficiency of applying agricultural chemicals by aircraft.

Water Quality Monitor

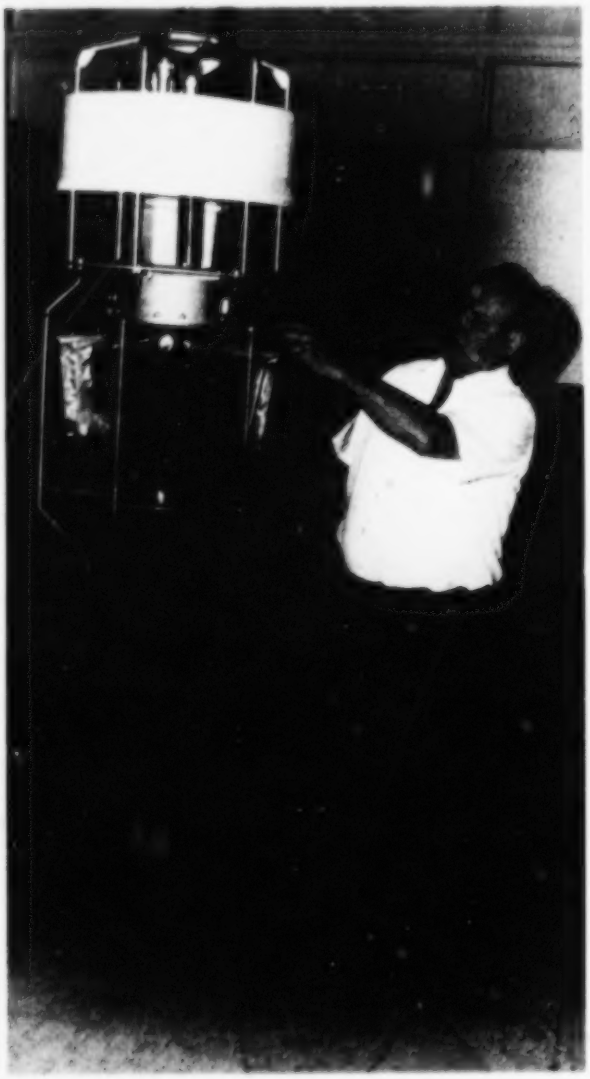
To meet a need of the Environmental Protection Agency (EPA), Langley Research Center has developed an automated Water Quality Monitoring System based on aerospace microelectronics and data acquisition technologies. Designed for unattended operation in water depths up to 100 feet, the system consists of a subsurface buoy anchored in the water, a surface control unit (SCU) and a hydrophone link for acoustic communication between buoy and SCU.

The subsurface buoy—shown being lowered into the water (below) and in laboratory view (right)—is the primary functional unit. It incorporates 16 cells for water sampling, plus sensors for eight water quality measurements, such as temperature, pressure, alkalinity, dissolved oxygen, fluoride content and other conditions. The buoy contains all the electronic equipment necessary for collecting and storing sensor data, including a microcomputer and a memory unit. Power for the electronics is supplied by a nickel cadmium battery designed to operate for two weeks before recharge is required.

Through the hydrophone link, the subsurface buoy reports its data to the SCU, which relays it to land stations. The link allows two-way communications, so the SCU can send instructions to the buoy, for example, commands to transmit data or to change the water sampling schedule. If the buoy springs a leak or runs low on battery power, the system automatically shuts down and sends a "pinging" alert signal. For recovery, a sequence of commands sent via the hydrophone link causes the buoy to release from its anchor and float to the surface for pick-up by boat; a locator pinger guides the boat crew to the buoy's position.



The monitor demonstrated its ability to provide voluminous water quality data in a seven-day field test at Saginaw Bay, an eastern Michigan arm of Lake Huron. In these tests, the system used only one-third of its battery energy supply, indicating that it could function well beyond the design goal of two weeks. On completion of the field tests, the monitor was turned over to EPA's Large Lakes Research Station, Grosse Ile, Michigan.



Forestry Vehicle

During the Apollo program, NASA planned development of an unmanned, remotely-controlled vehicle to roam the lunar surface and report data over a long period. Conducted by Johnson Space Center, the research effort included work on a "load equalization system", a method of suspension that would allow the vehicle to negotiate craters and boulder fields or to climb very steep slopes; the suspension kept all four wheels on the ground whether the rover was pitching sharply up and down or rolling from side to side. The rover never became operational, but the technology has found application in the vehicle pictured. Called Power Pack II, it provides an economical means of moving a power source into remote, roadless forest areas.

Foresters need power to run equipment for logging, planting, pumping water, building trails and other operations. Getting the power to all-but-inaccessible areas is a problem. Helicopters or specially-designed "skidders" are expensive; human haulage is limited to relatively light, low-power equipment. Power Pack II fills a gap; it is an intermediate-sized unit which carries a power source and the powered tools to perform a variety of forest management tasks which cannot be done economically with current equipment.

The "self-propelled forestry power pack" was developed by Professor John Miles and his associates in the Agricultural Engineering Department of the University of California, Davis (UCD), working in cooperation with the California Department of Forestry. The UCD team combined its own design of an all-terrain vehicle with a suspension system based on the NASA load equalization technology. The result is a machine which can traverse very rough terrain and climb a 60 degree slope; any one of the wheels can move easily over an obstacle larger than the wheel's own diameter. The UCD group is now working on a more advanced Power Pack III.

NASA and Mt. St. Helens

On March 20, 1980, Washington's Mt. St. Helens volcano ended 123 years of dormancy with a single small earthquake, followed a week later by the first of several eruptions. The major eruption occured on May 18 (below), when the volcano, exploding with the estimated force of a 10-megaton bomb, spewed clouds of gases and aerosols into the stratosphere to heights of almost 15 miles. During the rest of 1980 and into 1981, the volcano's ejecta was the subject of intense study by scientists from a score of organizations. NASA technology played an important part in the Mt. St. Helens aftermath, not only in scientific studies but also in disaster assessment and relief operations.

A technology demonstration of special interest, because of its applicability to future disasters, involved an innovative way of providing communications for emergency operations after much of the area's communications was quickly disabled. A particular problem was maintaining communications with the multitude of rescue ground crews and evacuation helicopters operating in the smoke-obscured area (top right).

A solution was provided through a coordinated effort involving local authorities, NASA, the Air Force, the National Guard, the National Association for Search and Rescue, the Federal Emergency Management Agency and General Electric Company (GE). The key elements of the emergency system were NASA's ATS-3 satellite (right) and a communications jeep developed by the USAF's 303rd Air Rescue and Recovery Service, March Air Force Base, California. Built by GE, the ATS-3 is capable of beaming to and receiving signals from small, simple antennas on the ground. The Air Force jeep was equipped with such an antenna and with additional equipment for sending or receiving signals over a broad range of radio frequencies. The jeep ATS-3 handled a large portion of search/rescue and disaster relief communications during the critical early stage. For communications to points outside the disaster area, ATS-3 sent its signals to GE's Earth Station Laboratory, Rome, New York, which relayed them through commercial telephone lines.

In addition to the communications effort, NASA technology contributed to an assessment of the environmental impact of the Mt. St. Helens eruptions. Specially-instrumented aircraft operated by Ames Research Center, Johnson Space Center, Langley Research Center and Wallops Flight Center took samples of the volcanic material at various points over the United States and tracked the volcano's plume as far east as the Atlantic Ocean and Europe. A NASA instrumented balloon penetrated the plume over Wyoming and measured stratospheric dust concentrations 400 to 1,600 times normal. NASA's Stratospheric Aerosol and Gas Experiment satellite also tracked the global spread of the volcanic "veil" from its orbital vantage point. The data from all these operations provided important input to NASA's ongoing studies of how the atmosphere reacts to aerosol injections caused by human activities or natural events, how these particles are transported around the world, and what effect they may have on local, regional and world climate.

Forest Fire Observation

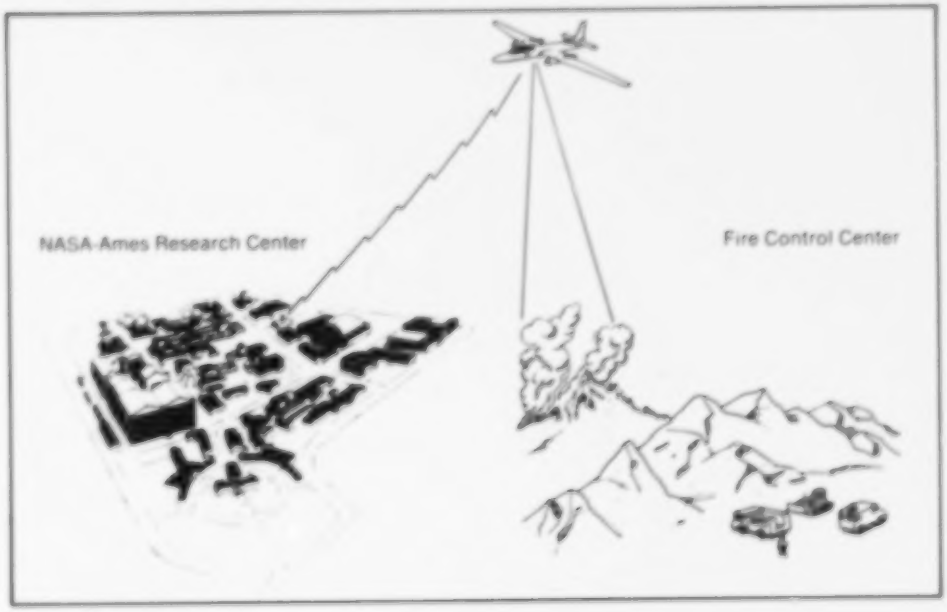
Timely information about conditions on the perimeter of a forest fire is difficult to obtain. Inaccessibility of the terrain hampers ground observation and aerial views of the fire are obscured by smoke. Ames Research Center has demonstrated how these difficulties can be surmounted by use of airborne remote sensing techniques such as those regularly employed by the Center in earth resources survey operations.

In a 1980–81 series of flights, an Ames U-2 high-altitude survey aircraft served as an aerial fire observation system capable of "seeing" through the smoke. Equipped with two types of sensors, the U-2 produced real-time infrared images of fireground scenes, providing significant advantages over conventional fire monitoring practices.

The U-2's service in a fire at Kings Canyon National Park, California exemplifies the utility of airborne remote sensing. At Kings Canyon, thick smoke blocked visibility from the air and treacherous terrain made deployment of firefighters dangerous in the absence of a known fire perimeter. The information acquired by the U-2's scanners defined the fire boundary and aided fire management decisions by showing the size, shape and direction of burn and the location of hot spots in the fire zone. The comparison views (left) illustrate the advantages of remote sensing: in the upper view, taken by a conventional aerial camera, the fireground is totally obscured by smoke; in the infrared image, the fire boundary is clearly defined.

The diagram (below) describes the Ames fire observation process. Flying over a fireground at about 65,000 feet, the U-2 sends sensor data in digital form to an antenna at Ames Research Center. There the data is computer-processed into images, which are overlaid on U.S. Geological Survey topographical maps of the fire area. The maps are then transmitted by telecopy machine directly to the fire control center. The whole process, from U-2 to fire camp, takes less than 10 minutes and the U-2 has sufficient endurance to provide fire propagation information for five hours.

The Ames antenna can pick up signals from the U-2 anywhere within a 300-mile radius from Ames, thus allowing coverage of virtually all forest land in California. Coverage could be increased by adding other ground stations, and transmission via satellite would allow real-time fire observation anywhere in the world.



Technology Utilization

A description of the mechanisms employed to encourage and facilitate practical application of new technologies developed in the course of NASA research and development activities and those of the agency's contractors

Recycling Technology

In a comprehensive nationwide effort NASA seeks to increase public and private sector benefits by broadening and accelerating the secondary application of aerospace technology

Located at the University of Georgia, NASA's Computer Software Management and Information Center (COSMIC)® makes available to industry, government and other organizations computer programs that have secondary applicability.

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Technology's role as an invigorant for economic growth is well established. A nation's accumulation of technical knowledge provides a foundation for development of new products and processes, and leads to more effective use of labor, capital and natural resources; this adds up to expanded productivity. Increased productivity means more jobs, more wages, greater profits for management and higher levels of national income. In short, productivity is the key element of a nation's prosperity, and technology is its pump-primer.

Thus, the wealth of aerospace technology generated by NASA programs over the past 24 years is a valuable national resource. Since technology is transferable, this wealth of aerospace lore is an important asset in that it offers potential for new applications. It becomes even more important when that potential is translated into reality, when the technology is put to work as a stimulant to productivity.

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A network of Industrial Applications Centers and State Technology Applications Centers, located at universities across the country, provides information retrieval services and technical assistance to industry and government clients.

That is one of NASA's jobs. The instrument of stimulus is the Technology Utilization Program. Simply stated, the program's aim is to get aerospace technology out of the storehouse and into the mainstream of the national economy, thereby producing bonus return on the aerospace investment. The program encourages secondary use of the technology emerging from NASA's mainline research effort by identifying new ways to employ the technology productively and by making the technology more readily available to prospective users.

In drafting the legislation that became the National Aeronautics and Space Act of 1958, the Congress took due note of the potential value of aerospace generated know-how. A provision of the Act requires that NASA "shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

NASA has responded to that mandate in impressive fashion. In 1962, the agency established the Technology Utilization Program, a concerted effort designed to accelerate and broaden the transfer of aerospace technology to other sectors of the economy. In the 20 years that have since elapsed, literally thousands of spinoffs have been effected; they range from simple everyday conveniences to major systems that help solve some of society's pressing problems.

Focal point of the program is the Technology Utilization and Industry Affairs Division, headquartered in Washington, D.C., which coordinates the activities of a nationwide network of technology transfer catalysts. These technologists provide a link between the developers of aerospace technology and those who might effectively reuse the technology in non-aerospace applications. Their job is to keep abreast of aerospace technical advances, seek opportunities for secondary utilization, promote interest among prospective users, and provide assistance to expedite the transfer process.

NASA employs a variety of mechanisms to meet the objectives of the Technology Utilization Program. Amplified on the following pages, they include:

- Technology Utilization Officers, located at NASA field centers, who serve as regional program managers.
- A number of Industrial Applications Centers, channels through which industrial and other potential users may avail themselves of scientific, technical and management information and expertise.
- State Technology Applications Centers, which focus on opportunities for applying aerospace technology to the specific problems and needs of their state and local governments.
- Application Teams, multidisciplinary groups of technologists who provide technology-matching and problem-solving assistance to public and private organizations.
- Applications engineering projects, in which NASA undertakes, in concert with other organizations, to adapt existing aerospace technology to meet specified needs of other government agencies and public sector institutions.
- A Computer Software Management and Information Center, which provides aerospace-developed and other computer programs adaptable to the needs of industry and government agencies.
- A quarterly publication, *Tech Briefs*, which informs potential users of new technologies available for transfer.

Applications Centers

To promote technology utilization, NASA operates a network of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government clients. The network consists of seven Industrial Applications Centers (IAC) and two State Technology Applications Centers (STAC) affiliated with universities across the country, each serving a geographical area. The centers are backed by off-site representatives in many major cities and by technology coordinators at NASA field centers; the latter seek to match NASA expertise and ongoing research and engineering with client problems and interests.

The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval. Through the applications centers, clients have access to more than 10 million documents. Almost two million of these documents are contained in the NASA data bank, which includes reports covering every field of aerospace-related activity plus the continually updated selected contents of 15,000 scientific and technical journals.

Intended to prevent wasteful duplication of research already accomplished, the IACs endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems. By taking advantage of IAC services, businesses can save time and money and the nation benefits through increased industrial efficiency.

Staffed by scientists, engineers and computer retrieval specialists, the IACs provide three basic types of services. To an industrial firm contemplating a new research and development program or seeking to solve a problem, they offer "retrospective searches"; they probe appropriate data banks for relevant literature and provide abstracts or full-text reports on subjects applicable to the company's needs. IACs also provide "current awareness" services, tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields with a minimal investment of time. Additionally, IAC engineers offer highly skilled assistance in applying the information retrieved to the company's best advantage. The IACs charge a nominal fee for their services.

The State Technology Applications Centers supplement the IAC system. They facilitate technology transfer to state and local governments, as well as to private industry, by working with existing state mechanisms for providing technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state. For further information on IAC/STAC services, interested organizations should contact the director of the nearest center; addresses are listed in the directory that follows.

Publications

An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This aim is accomplished primarily through the publication *Tech Briefs*.

The National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. Those reports provide the input for *Tech Briefs*. Issued quarterly, the publication is a current-awareness medium and a problem-solving tool for its many industrial subscribers. Each issue contains information on approximately 140 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on a particular product or process described in the publication. Innovations reported in *Tech Briefs* last year generated more than 160,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader secondary use of NASA technology.

Subscription to *Tech Briefs* is free to engineers in U.S. industry, business executives, state and local government officials and other qualified technology transfer agents. The publication may be obtained by contacting the Director, Technology Utilization and Industrial Affairs Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240.

A related publication deals with NASA-patented inventions available for licensing, which number more than 3,500. NASA sometimes grants exclusive licenses to encourage early commercial development of aerospace technology, particularly in those cases where considerable private investment is required to bring the invention to the marketplace. Non-exclusive licenses are also granted, to promote competition and bring about wider use of NASA inventions. A summary of all available inventions, updated semi-annually, is contained in the *NASA Patent Abstracts Bibliography*, which can be purchased from the National Technical Information Service, Springfield, Virginia 22161.

Technology Applications

One facet of NASA's Technology Utilization Program is an applications engineering effort, which involves the use of NASA expertise to redesign and reengineer existing aerospace technology for the solution of problems encountered by federal agencies, other public sector institutions or private industries.

Applications engineering projects originate in various ways. Some stem from requests for NASA assistance from other government agencies; others are generated by NASA technologists or application teams who perceive possible solutions to public sector problems by adapting NASA technology to the need. NASA employs two application teams, each composed of several scientists and engineers representing different areas of expertise. These teams contact public sector agencies, medical institutions, trade and professional groups to uncover problems that might be susceptible to solution by application of NASA technology.

A project involving adaptation of space communications technology to improvement of highway traffic flow exemplifies the technology applications effort. Developed by Jet Propulsion Laboratory (JPL), the NASA technology is known as compressed television transmission, or CTT. It is a means of compressing the digital data that represents an image observed by a remote sensing system aboard a spacecraft—for example, a picture of a planet—so that more information can be transmitted to Earth in a given period of time. At an Earth station, the compressed data stream is "decompressed" and processed to produce high-quality images. This technology offers a means of alleviating highway congestion caused by "incidents"—accidents or breakdowns—that create bottlenecks.

To combat the congestion problem, a number of state transportation agencies have installed or are considering installation of traffic surveillance systems employing closed circuit television; the TV pictures, relayed to a control center, identify the location and cause of congestion, helping to reduce incident response time. TV transmissions are accomplished by coaxial cable or by microwave, both expensive; microwave transmission has an added disadvantage in that it cannot be used in many urban areas due to Federal Communications Commission restrictions on frequency allocations. The JPL data compression technology offers a cost-effective substitute because it makes possible the use of telephone lines for transmissions. Estimates indicate that CTT using telephone lines costs less than $10,000 per mile, compared with $30,000 to $70,000 a mile for the other methods; this is a big factor where a surveillance system might cover several hundred miles.

Under NASA funding, JPL developed a CTT prototype system for telephone line transmission from cameras located on highway overpasses. An operator in the control center can send signals to control the pan, tilt and zoom of the TV cameras and select the rate at which TV frames are transmitted; the slower the frame rate, the better the quality. In the accompanying images, at left above is an uncompressed picture which takes 51 seconds to transmit. In the center is a CTT image transmitted at a rate of three seconds per frame; its quality is close to that of the uncompressed image. At faster frame rates, there is some degradation of quality, but even at one second per frame (right) the picture is acceptable for traffic surveillance.

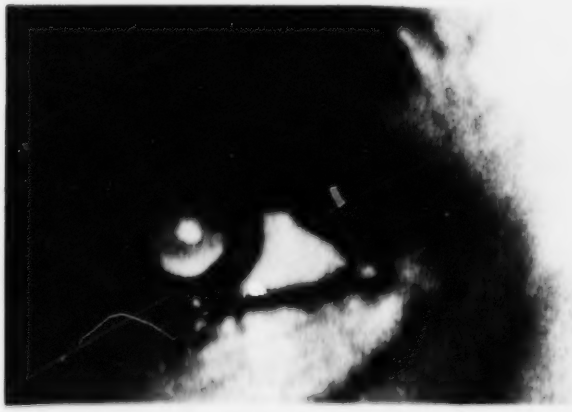
The CTT technology will be employed this year, on a demonstration basis, by the Maryland Department of Transportation, which is planning a traffic surveillance and control system for the Baltimore Beltway.

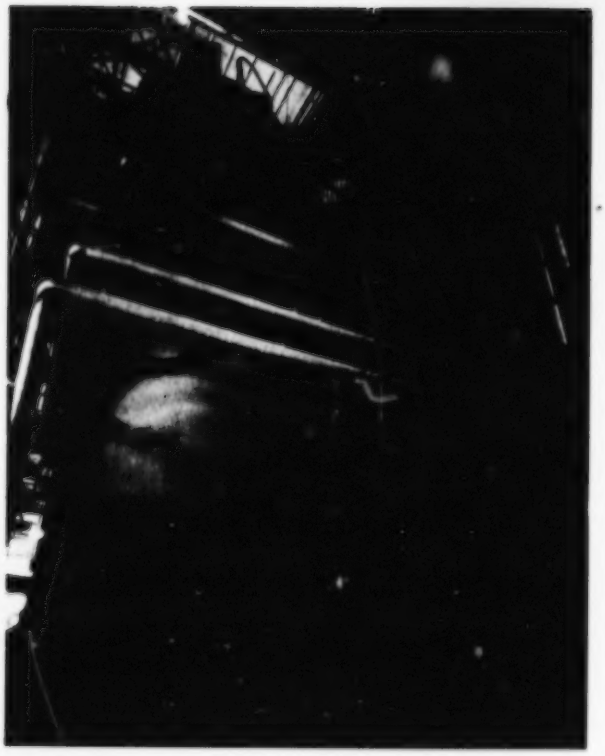
The SRI International Technology Application Team, Menlo Park, California contacted several manufacturers of slow-scan TV systems in an effort to promote commercialization of the JPL technology. One—Dalmo-Victor Operations of Bell Aerospace Company, Belmont, California—has taken steps to add the system to its product line. The SRI team also made a survey of potential users in areas other than transportation and found that substantial markets exist in such CTT applications as remote medical diagnosis, hospital patient monitoring, teleconferencing, transit station surveillance and security monitoring of military and industrial installations.

Another technology application example is a project for development of an Ocular Screening System, a much-needed quick and accurate method of detecting eye defects. The system has many applications related to eyesight problems, but it can be especially valuable in screening infants and other non-communicative persons for amblyopia, poor vision even with use of corrective glasses; untreated, amblyopia can result in vision degradation, perhaps total blindness. Children should be screened frequently for amblyopia, but screening programs have not been instituted in the United States due to lack of a simple, reliable, fast and relatively inexpensive method. The Ocular Screening System is intended to fill that need. Its development is being jointly funded by NASA and Electro-Optics Consultants (EOC), Inc., Huntsville, Alabama. Marshall Space Flight Center is program manager and additional support is provided by the Research Triangle Institute Application Team, Research Triangle Park, North Carolina.

The NASA/EOC system is a means of recording the retinal reflex that occurs when human eyes are exposed to a flash of light. The system (top) consists of a 35 millimeter camera with a telescopic lens and a strobe light. In a screening test, the strobe sends light into the subject's eyes (right) from a distance of 21 feet; the light is reflected from the retina back to the camera lens and onto color film. NASA image processing technology is being used to evaluate the information in the retina reflex images. In the color pictures, two healthy eyes will have pupils that appear red and have identical images, as in the photo at left below. When the pupils appear different, it is an indication of an eye defect; the nature of the defect is identified by the visual evaluation of a trained observer. The photo below shows pupil differences determined to be cataract in the left eye.

The system offers rapid screening at relatively low cost and has the added advantages that no special examination room is required and the subject need do nothing but look at the lens. It not only isolates amblyopia and pre-amblyopic conditions, it is also useful in detecting other eye diseases in their formative stages and in evaluating treatments. In Alabama tests last year, retina reflex analyses of 232 persons were performed with an accuracy of 90 percent. EOC is building two prototype units for additional evaluations this year in the Dallas (Texas) school system and at Smith Kettlewell Institute, San Francisco, California.





Software Center

In the course of its varied activities, NASA makes extensive use of computers, not only in Space Shuttle missions but in such other operations as analyzing data received from satellites, conducting aeronautical design analyses, operating numerically controlled machinery and performing routine business or project management functions. Operation of computers requires software, computer programs that are essentially sets of instructions telling the computer how to produce desired information or effect from its stored input. Thus, NASA and other technology-generating agencies of the government have of necessity developed many types of computer programs, a valuable resource available for reuse. Many of these programs are directly applicable to secondary use with little or no modification; some can be adapted for special purposes at far less than the cost of developing a new program from scratch.

To help industrial firms, government agencies and other organizations take advantage of this type of technology utilization, NASA operates the Computer Software Management and Information Center (COSMIC). Located at the University of Georgia, COSMIC collects, screens and stores computer programs developed by NASA and other government agencies. The Center's library contains more than 1,500 programs, which perform such tasks as structural analysis, design of fluid systems, electronic circuit design, chemical analysis, determination of building energy requirements and a variety of other functions. COSMIC offers these programs at a fraction of their original cost and the service has found wide acceptance.

An example of COSMIC's service is its assistance to Ingersoll-Rand Company, Woodcliff Park, New Jersey, which manufactures large circulating pumps such as the one shown at left. In designing impellers for the pumps, the company makes use of a NASA-developed,

COSMIC-supplied computer program known as MERIDL. The program makes flow analysis calculations that permit designers to evaluate the performance and efficiency characteristics that can be expected from the pump's impeller. MERIDL also provides information that enables a trained hydraulic engineer to make design improvements.

Ingersoll-Rand's Research Center, Princeton, New Jersey acquired the program from COSMIC and assisted Pump Group hydraulic designers in using it in the design process. An example of a product whose design was aided by MERIDL is the unit above, an impeller for a large vertical circulating pump used to pump sea water into a desalinization plant in Saudi Arabia. Ingersoll-Rand also uses a companion COSMIC program called TSONIC for analyzing flow velocities in pumps, compressors and turbines.

To assist prospective customers in locating potentially useful programs, COSMIC publishes an annual indexed catalog of all the programs in the Center's inventory. Available on either microfiche or computer magnetic print tape, the catalog may be purchased directly from COSMIC. The Center also helps customers define their needs and suggests programs that might be applicable. For information on COSMIC's services, contact the director at the address in the directory that follows.

NASA's Technology Transfer Network

The NASA system of technology transfer personnel and facilities extends from coast to coast and provides geographical coverage of the nation's primary industrial concentrations, together with regional coverage of state and local governments engaged in transfer activities. For specific information concerning the activities described below, contact the appropriate technology utilization personnel at the addresses listed on the following pages. For information of a general nature about the Technology Utilization Program, address inquiries to the Director, Technology Utilization and Industry Affairs Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240, or phone (301) 859-5300, ext. 210.

■ *Field Center Technology Utilization Officers*: manage center participation in regional technology utilization activities.

● *Industrial Applications Centers*: provide information retrieval services and assistance in applying relevant technical information to user needs.

□ *State Technology Applications Centers*: provide technology transfer services similar to those of the Industrial Applications Centers, but only to state governments and small businesses within the state.

▽ *The Computer Software Management and Information Center (COSMIC)*: offers government-developed computer programs adaptable to secondary use.

▲ *Application Teams*: work with public agencies and private institutions in applying aerospace technology to solution of public sector problems.

Field Centers

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, California 94035

Technology Utilization Officer: *Stan Miller*
Phone: (415) 965-6471

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 344-6242

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas 77058

Technology Utilization Officer: *John T. Wheeler*
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899

Technology Utilization Officer: *U. Reed Barnett*
Phone: (305) 867-3017

Langley Research Center
National Aeronautics and Space Administration
Langley Station
Hampton, Virginia 23655

Technology Utilization and
Applications Programs Officer: *John Samos*
Phone: (804) 827-3281

Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135

Technology Utilization Officer: *Harrison Allen, Jr.*
Phone: (216) 433-4000, ext. 422

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Director, Technology Utilization Office: *Ismael Akbay*
Phone: (205) 453-2223

Wallops Flight Center
National Aeronautics and Space Administration
Wallops Island, Virginia 23337

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, ext. 201

Resident Office
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Technology Utilization Officer: *Aubrey D. Smith*
Phone: (213) 354-4849

Industrial Applications Centers

Aerospace Research Applications Center
1201 East 38th Street
Indianapolis, Indiana 46205

John Ulrich, director
Phone: (317) 264-4644

Kerr Industrial Applications Center
Southeastern Oklahoma State University
Durant, Oklahoma 74701

James S. Harmon, Ph.D., director
Phone: (405) 924-0121, ext. 413

NASA Industrial Applications Center
701 LIS Building
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Paul A. McWilliams, Ph.D., executive director
Phone: (412) 624-5211

NASA Industrial Applications Center
University of Southern California
Denney Research Building
University Park
Los Angeles, California 90007

Robert Mixer, Ph.D., director
Phone: (213) 743-6132

New England Research Applications Center
Mansfield Professional Park
Storrs, Connecticut 06268

Daniel Wilde, Ph.D., director
Phone: (203) 486-4533

North Carolina Science and
Technology Research Center
Post Office Box 12235
Research Triangle Park, North Carolina 27709

James E. Vann, Ph.D., director
Phone: (919) 549-0671

Technology Applications Center
University of New Mexico
2500 Central Avenue, S.E.
Albuquerque, New Mexico 87131

Stanley Morain, Ph.D., director
Phone: (505) 277-3622

State Technology Applications Centers

NASA/Florida State Technology Applications Center
State University System of Florida
500 Weil Hall
Gainesville, Florida 32611

J. Ronald Thornton, director
Phone: (904) 392-6626

NASA/UK Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, Kentucky 40506

William R. Strong, manager
Phone: (606) 258-4632

Computer Software Management and Information Center

COSMIC
112 Barrow Hall
University of Georgia
Athens, Georgia 30602

John A. Gibson, director
Phone: (404) 542-3265

Application Teams

Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709

Doris Rouse, Ph.D., director
Phone: (919) 541-6980

SRI International
333 Ravenswood Avenue
Menlo Park, California 94026

James P. Wilhelm, director
Phone: (415) 326-6200, ext. 3520

NASA
National Aeronautics and
Space Administration

Director, Technology Utilization and
Industrial Affairs Division
P O Box 8757
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